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## Mining and Metallurgical Section.

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### THE MINING AND MINTING OF GOLD AND SILVER.

ABSTRACT OF AN ADDRESS BY ALEXANDER E. OUTERBRIDGE, JR., President of the Section.

The speaker said that as the increasing production of precious metals all over the world is attracting much attention, not only in the metallurgical world but from students of political economy, statesmen and others, he thought that a few reminiscences of his early experiences, commencing nearly thirty years ago and covering the period in which occurred the beginning of the greatest development of silver mining in this country, might prove interesting at the present time.

In 1869, the year in which the speaker entered the assay laboratory of the Mint as an assistant, the output of silver in the United States amounted in coining value to $12,000,000; in 1870 to $16,000,000; in 1871 to $23,000,000; in 1872 to $28,750,000.

In 1873, the year in which the "trade dollar" was created by Act of Congress, the production of silver amounted to $35,750,000.

In 1878, the year in which the Bland Bill was passed by Congress over the President's veto, the output of silver was reported by the Bureau of the Mint to have been $45,200,000. In 1892 the figures were $82,101,000. In the following year production declined to $77,576,000, and in 1897 the output was $69,637,172.

These official figures all refer to coining values and to calendar years. The commercial value of fine silver has fallen from $1.32 an ounce in 1869, to about 61½ cents an ounce at the present day. The commercial value of the silver product of 1897 was $32,316,000.

The production of gold has not kept pace with that of silver in this country, notwithstanding the considerable increase in the past few years. The output of gold from 1873 to 1896 inclusive, as determined by the Bureau of the Mint, was 42,751,613 fine ounces; the output of silver in the same period was 998,411,000 fine ounces.

High water-mark in the production of gold was reached as long ago as the year 1853, when the output was 3,144,374 fine ounces (value, $65,000,000). In 1869 the output was 2,394,563 fine ounces ($49,500,000) and, with one or two exceptions, each subsequent year showed decreasing production until 1883, when the minimum amount of 1,451,250 fine ounces ($30,000,000) was recorded. Each year since has shown an increase, and in 1897 the gold product of the United States was 2,774,935 fine ounces, of the value of $57,363,000.

The report of the Director of the Mint upon the production of the precious metals for the calendar year 1897, recently submitted to the Secretary of the Treasury, contains some impressive figures.

It is shown that the production of gold in the United States increased $4,275,000 in 1897 over that of 1896. South Africa made a gain of $13,854,192, Australasia a gain of $10,502,249, and Russia a gain of $1,709,970 in the same period of time.

In 1897, the value of the total gold product of the world is stated to have been $237,504,800, and that of the total silver $236,730,300 (coining value).

In 1887 the total production of gold is shown (in other official tables) to have been $105,774,900, or less than one-half that of 1897, and the total production of silver was $124,281,000, or a little over one-half that of 1897.

If we go back still farther to the decade 1811 to 1820, inclusive, we find that the total production of gold in the world during this period was but $76,063,000, or less than one-third of the production in the single year 1897, and the production of silver in any single year of that decade was less than one-tenth of the production in 1897. The production of gold in 1897 was almost exactly equal in value to the entire production of the world during the quarter of a century from 1811 to 1836!

The production of gold in the United States in 1897 was not the largest in the history of this country, as already stated, but it was the largest since 1854. In that year gold was produced to the value of over two and a half million dollars more than in 1897, while in the previous year, 1853, there was produced more than eight and a half million dollars in value of gold in excess of the output of 1897. The enormous production in 1853 and 1854 was due to the discoveries of placer gold in California. These were the banner years and production of gold in the United States gradually declined from that time until it reached the lowest ebb, in 1883, when it amounted to but $30,000,000 in value.

About fifteen years ago, improved methods of getting gold from low grade ores, and of refining base bullion and "doré" bullion (silver containing a small percentage of gold) began to be commercially developed, and in consequence thereof the production of gold has increased year by year. For these, and other reasons, it seems probable that the yearly production of gold in the future will show a gradual increase and will be less subject to fluctuations than it has been in the past.

While it is true that nuggets, grains and dust are still found by prospectors in newly-explored regions, most of the

gold is now obtained from widely distributed low grade ores by the aid of scientific processes. Notwithstanding the excitement over the Klondike discoveries, the output from that region is insignificant so far when compared to the total product of the country. Statistics show that the State of Colorado alone added twice as much gold to the world's stock in 1897 as did the Klondike region, and several other States largely exceeded the Klondike output.

The statement of the Director of the Mint that the gold product of the South African Republic exceeded that of the United States in 1897, is apparently creating much astonishment and comment just now, but the monthly returns (unofficial) from that region show that the output for ten months of the present year exceeded that of the entire year 1897, and it is estimated that South Africa's contribution in 1898 to the world's stock of gold will not be far short of $70,000,000!

American mining engineers who have been engaged in developing the South African gold fields have computed from surveys of the ground and numerous assays of samples of ore taken from different localities and at different depths that the gold contained in the ore in sight in the district known as the "Rand," or Witwaatersrand, amounts to the enormous value approximately of $4,000,000,000, and at the present rate of production it will take half a century to exhaust these deposits, even though no further discoveries be made. Australasia and the United States together produced more than one-half of the entire output of gold in 1897, and it is in these two countries that modern methods have been most largely adopted. Gold getting has been changed by modern scientific methods from a lottery to a comparatively safe even if more prosaic business, and for this reason, if for no other, the suitableness of this noble metal for use as a universal measure of value, is rendered even more apparent than in former years when the production was subject to greater fluctuations. The increase in production is keeping pace with increase in population, and the leading nations have long realized that while in former ages, beads, shells, skins, cattle, tobacco, farm products, tin, lead,

copper, and other metals have served useful ends as money; there is, in the present stage of development of civilization, but one material adapted to fulfil the function of a universal measure of value of all commodities, including labor, and this is the metal gold, which is, fortunately for mankind, so widely yet sparingly distributed that the increasing requirement for this purpose and increasing supply seem to regulate each other in a truly wonderful way.

Owing partly to the increasing magnitude of silver deposits at the Philadelphia Mint, commencing about 1871, and partly to a natural predilection for the analytical methods of the "humid assay" of silver, this work became the speaker's special occupation during the following ten years. Assays of silver increased from an average of about a dozen per day in 1870, to more than one hundred on many days in 1876, owing largely to the coining of "trade dollars," of which 35,965,924 in all were struck before this coinage was suspended.

After the passage of the Bland-Allison Act, in 1878, the silver deposits and assays increased to a still greater degree.

In 1881, the year in which the speaker resigned from the Mint to become the metallurgist of a private manufacturing establishment, the production of silver in the United States was nearly four times greater than in 1869, when he first entered the assay laboratory.

In 1873 Sir Norman Lockyer, the astronomer, and Professor Roberts-Austen, chemist of the Royal Mint, London, announced to the Royal Society that they had discovered a quantitative method of assay of gold and silver by means of the spectroscope, which they expected would supersede the chemical methods then in use, and the speaker was thereupon authorized by the chief assayer of the Mint in Philadelphia to make a thorough study for the assay department of the proposed method.

The assayer caused to be made alloys of gold and copper, gold and silver, and gold, silver and copper; these were carefully assayed, numbered, and delivered to the speaker, who took them to a private laboratory in the University of Pennsylvania, set apart for this experimental work, in which

there was placed for his use, by the courtesy of the professor of physics, a large spectroscope, a powerful Ruhmkorff coil and galvanic battery. Here the study of the spectra of the gold and silver alloys was carried on daily for over six months, a special instrument having been devised for holding the specimens, and constructed in the Mint by the late S. James, master mechanic.

A report was made in 1874 to the assayer, which was communicated by him to the American Philosophical Society, and published, with photo-relief reproductions of the original drawings, in their Proceedings (Vol. XIV, No. 93, *Trans. Am. Ph. Soc.*).

The Chief Assayer of the Mint, the late W. E. DuBois, in presenting this report to the American Philosophical Society, on May 16, 1874, gave the following introduction:

"It must have occurred to many, when the brilliant spectroscopic method of scientific research succeeded in detecting the presence of metals, in any given substance, even to an infinitesimal nicety, that the next step must be to determine the proportion of such presence; in other words, the qualitative must lead to the quantitative, as in other chemical processes.

"The Annual Report of the Royal Mint at London for 1872 (dated April 15, 1873) contains an official memorandum of Mr. W. Chandler Roberts (now Roberts-Austen), chemist of the Mint, from which it appears that he was engaged in examining this subject, at the suggestion of, and in connection with, the distinguished spectroscopist and astronomer, Mr. (now Sir) J. Norman Lockyer. No decided results had been reached; but Mr. Roberts concluded by expressing the belief that every effort should be made to render the instrument serviceable in the operations of minting. . . It seemed desirable that our own Mint should maintain its character for examining and adopting real improvements, and not wait indolently to hear what might be done abroad.

"One of the assistants in the Assay Department, Mr. Alex. E. Outerbridge, Jr., had, for several years, given special attention to spectroscopic studies, both in theory and

in practice, and to him therefore the subject was committed; with what propriety and what success will sufficiently appear from what he has written. This will be found in the two following communications to the Assayer.

"The details he has given are well worth careful study; but we cannot help noticing, in a few words, the astonishing paradox at which his experiments arrive; namely, that this method is, in one respect, by far too sensitive and minute; and in another respect far from being minute enough, to serve the uses of the assay. It was worth all his patient labor many times over to come to this conclusion, as we must come, in the present state of this branch of science. And it is likely that the natural and necessary imperfections of metallurgy, the want of complete atomic homogeneity in the mixing of metals, will forever prevent the spectroscope from taking the place of the present methods of assay.

"As Mr. Outerbridge has been careful to give facts rather than suppositions, he has omitted any explanation of the anomalous results in the final part of his report. And yet, it seems evident that where two metals are present, the spark will, to some extent, elect for its vehicle the one which is most readily vaporized. This is notably shown in alloys of gold with copper. It is also very striking in the alloy of nickel and copper, of which our 5-cent piece is made. The nickel, which constitutes one-fourth, controls the color of the alloy entirely; and yet, being far more difficult of fusion than the copper, scarcely shows a trace in this spectrum analysis. . . .

"These experiments, it is believed, will be of use to show what may, and what may not, be expected from the spectroscope in the way of analysis where several metals are components.

"They may also be of use in other departments of investigation."

The report showed conclusively that the novel method, though interesting from a scientific point of view, was not practical, owing partly to the almost infinitesimal amount of metal volatilized by the spark, which metallic vapor was

the subject of quantitative analysis by the spectroscope. The report was reprinted in the *Journal of the Franklin Institute*, the (London).*Quarterly Journal of Science* and other foreign journals, and its conclusions were, it is believed, accepted as final, and the chemical methods of assay still prevail.

The speaker said that an unexpected appointment, in 1876, as Resident Commissioner to the Centennial Exposition from one of the smaller colonies of Great Britain resulted in forming pleasant acquaintances and valuable connections with several other foreign commissioners representing important gold-producing regions of the world.

The exhibit of gold ores, nuggets and minerals from Australia was particularly fine. A notable feature was the display of fac-similes of the most famous gold nuggets that had been found in Australia. One of these, discovered in 1869, called the "Welcome Stranger," weighed 2,268½ ounces, and was sold for £10,000 sterling.

The fac-similes were made of plaster of Paris, heavily coated with gold leaf, and dusted with ferruginous clay in certain spots and cavities, and it was said that they resembled the originals so closely, that they could scarcely be distinguished from the genuine nuggets even by a critical eye.

On his way to Philadelphia, the Australian Commissioner stopped for several weeks in London, in order to exhibit the collection at the Crystal Palace, or some similar building. The night before the opening day he was at work until a late hour with his assistants, and the last case unpacked contained these fac-similes; they were placed in a glass showcase with the labels attached, stating the value of each original nugget, and each card had a small word (fac-simile) in one corner.

The next morning the Commissioner was astonished to find a guard of metropolitan policemen drawn up in front of the showcase, and he then learned that the night watchman, discovering all this wealth of gold, as he supposed, exposed in a glass case, not even locked, called the superintendent of the building, who sent post-haste for an emergency guard.

One of these gilded fac-similes was secured by the speaker at the close of the Centennial Exhibition and deposited in the cabinet of curios at the Mint, where it has often been mistaken for a large lump of virgin gold.

In 1876, a pioneer of the South African gold fields visited the Centennial Exhibition and brought with him a number of valuable nuggets, which he subsequently deposited in the Mint. He was an intelligent Scotchman, and he said to the speaker, "After the rich alluvial gold shall have been all taken by prospectors, like myself, others will come with machinery and secure far more gold from the refuse ore than the pioneers ever dreamed of." This prediction has come true. The Transvaal now leads the world in annual production of gold.

The cyanide process of recovering gold from low grade ores has been brought to great perfection in South Africa by American mining engineers, and the most recent publication by Ellsler states that nearly one-third of the gold of the Rand is now obtained by this process.

The speaker said that, in 1881, he read a paper before the Numismatic and Antiquarian Society descriptive of minting methods, and as these are practically the same to-day as at that time, this description will still suffice to show the delicate chemical and metallurgical processes, and intricate mechanical operations that are necessary to convert the precious metals into the coin of the Nation.

*Minting Methods.*—The precious metals are never found in the pure state, and they are deposited at the Mint alloyed with other metals, and in a great variety of forms, such as native grains, dust, amalgam, bars or pigs, old jewelry, etc. The mixed metals are known under the generic name of "bullion."

The bullion is first weighed in the "deposit weigh-room," where several balances are kept for the purpose; the largest of these will weigh as much as ten thousand ounces in one draught, and the scale will readily turn, even when loaded to its full capacity, with a weight of one hundredth part of one ounce. The metal is then placed in a box provided with a cover and lock and taken to the "deposit melting-room." Here it is put in a crucible which has been previously heated in the melting furnace and covered with a thin coating of borax, which forms a sort of fluid glass, acting as a cover to protect the metal, when it is molten, from the oxidizing influence of the air. A workman, wearing a pair of large canvas mitts (somewhat resembling boxing gloves) grasps, with a pair of iron tongs, a rod or stick made of plumbago, he

stirs the now fluid mass back and forth, up and down, round and round, for the purpose of rendering it thoroughly homogeneous; the metal is then cast into an iron mould called a "shoe." It is plunged into water to cool, as well as to dissolve off any particles of the borax glass which may have adhered to its surface. It is now returned to the weigh room and reweighed.

A slight loss in weight usually occurs owing to a partial refining out of the base metals, and the new weight is the amount with which the depositor is credited.

Let us suppose that a depositor brings a miscellaneous assortment of old gold; watch cases, jewelry, dentist's plates, etc., representing every grade of fineness or proportion of pure gold, desiring to obtain its equivalent in coin. We will follow in imagination the usual course pursued.

After the metal has been returned from the melting-room (where it was cast into the shoe mould) and the bar reweighed, a small chip is cut off from one end of the bar and taken to the assay laboratory.

*The Analysis.*—The sample is laminated or rolled into a thin ribbon and stamped with the number of the deposit which it represents; it is then assayed to determine the proportion of gold, silver, and base metal, and so accurate are the processes of assay, that the exact value of a deposit, frequently aggregating many thousands of dollars in value, is determined to the fraction of a cent by calculations based on the assayer's report.

The largest weight which the assayer uses in making an analysis of gold bullion is the French half gram (or about seven and three-quarters grains troy).

The balances used in this work are marvels of mechanical construction; they are so sensitive that a weight of one-twentieth of a milligram (less than one-thousandth part of a single grain) will cause the indicator needle to deflect a very appreciable distance from the zero point on the graduated scale marking the equilibrium. These little balances are inclosed in glass cases, provided with sliding windows to exclude any draught of air. The beam is usually made of aluminum, one of the lightest metals, and the knife edges rest on jewels. The weights are made of gold, silver and aluminum, and are graduated from the half gram, which is arbitrarily denominated "1,000," down to the ten thousandth degree.

The assayer first determines approximately the relative proportions of the metals existing in the alloy, and from this bases his more careful determinations; he weighs out on the balance exactly one-half gram, or 1,000 parts of the alloy; he wraps this in an envelope of pure lead and rolls it into the form of a "bullet." The bullet is then placed in a small "cupel" or cup, made of calcined bone dust, which has been brought to a white heat in the muffle or oven of the assay furnace.

The mass melts immediately, and the lead oxidizes rapidly by absorbing oxygen from the heated air which passes continually over its surface, and on account of the extreme fluidity of the oxide it sinks into the pores of the cupel, which absorbs it as readily as a sponge absorbs water; the lead also carries with it all the base metals which may be originally combined in the alloy, but the precious metals not being oxidizable, simply melt, and are not so fluid as to be capable of sinking into the cupel. A separation thus takes place, and at the moment when all the base metal is removed, a beautiful

"flash" is observed to take place on the surface of the metal; the "button" of purified gold and silver resulting from this operation is then removed from the cupel, returned to the balance, and weighed; the loss indicates the proportion of base metal. Another weighing of the sample is then made, to which is added pure silver in the form of fine granules, in the proportion of about two parts of silver to one of gold, the alloy is enclosed in a sheet of lead and cupelled as before; the silver button remaining is laminated, coiled into a roll called a "cornet," and boiled in nitric acid. The acid dissolves the silver, leaving a little roll of nearly pure gold.* This gold cornet is then annealed in the furnace to give it toughness, and is finally weighed; this weight represents the proportion of pure gold. The proportion of silver is ascertained by subtracting the weight of the pure gold plus the weight of the base metal from the original weight of the assay sample.

Silver was formerly assayed in the same way, but it was long known that the result was not quite accurate, owing to a partial volatilization of the metal when exposed to the high temperature of the fire. Experiments were instituted by the French Government to overcome this difficulty, which resulted in the beautiful "humid process" devised by Gay-Lussac. This is one of the most accurate methods known to chemical science, and so complete was Gay-Lussac's original description that little room has been left for any improvements, and many thousands of dollars' worth of silver bullion are rapidly and accurately determined every day in the Mint in this way. The rationale of Gay-Lussac's method is very simple, viz.: a given amount of chlorine will precipitate a definite proportion of pure silver from its solution in nitric acid.

The assayer prepares two solutions of common salt water (chloride of sodium); one is known as the "normal solution," and the other as the "decimal solution" One begins and the other finishes the assay.

The sample of silver to be assayed is weighed out, as in the case of gold, the assayer taking care to place a sufficient weight of the alloy in the scale pan to contain at least one gram (a little over fifteen grains) of pure silver; the weighed sample is then placed in a glass bottle and a charge of nitric acid is added to it; the acid is caused to boil, and in a short time the silver alloy is completely dissolved.

A charge of the normal salt solution is then allowed to flow into the bottle from a glass "pipette," which is made of such a capacity that it shall contain just enough salt water to precipitate one gram of pure silver; the chlorine in the salt water combining instantly with the silver, precipitates it in the form of a white cloud; the bottle is agitated rapidly for a few moments, when the precipitate settles to the bottom, leaving a clear solution above; the assayer next allows a charge of the "decimal solution," which is one-tenth the strength of the normal solution, to flow into the bottle from a burette or glass tube with graduated divisions, each division marking one-hundredth the capacity of the large pipette. If any silver remains in the solution a cloud will be observed on the surface. Now, as this decimal charge is one-tenth the strength and one-hundredth the volume of the large pipette, it will, of course,

*A faint trace of silver remains undissolved by the acid, called the "sur-charge." The amount is ascertained by proof assays, using gold 1,000 fine, and proper allowance is made for the sur-charge of silver.

precipitate just one-thousandth as much silver, or one milligram. The bottle is again agitated to settle the precipitate, and successive charges of the "decimal solution" are added until all the silver is precipitated, and then a simple rule-of-three sum gives the exact proportion of pure silver contained in the original weight of the alloy. The assayer guards against all probable sources of error by an elaborate system of checks, and each set of assays is accompanied in all its mutations by one or more "proofs" or synthetic assays, made either from pure metal or from alloys of known composition.

After the exact proportions of gold, silver and base metal constituting the alloy have been reported by the assayer to the superintendent, the value of the deposit is calculated, and the depositor is paid the full equivalent, less the charges for refining, the amount of charges depending, of course, upon the nature of the bullion.

*The Refining Process.*—The metal now passes into the hands of the "melter and refiner."

We will suppose that the representative deposit that we have already alluded to contains a small percentage of base metals, such as tin and lead, which tend to make the alloy brittle or "short," rendering it unfit for coin. The first operation to which it is subjected is intended to eliminate these impurities, and is called "toughening." The metal is melted in a crucible and an oxidizing flux (saltpeter) is added to it while fluid, the saltpeter or niter decomposes and liberates oxygen gas; the oxygen seizes the base metals forming oxides; these rise to the surface and are dissolved in the flux; the flux, when sufficiently thick, is skimmed off, and the purified metal, consisting only of gold and silver, is poured into cold water to form granulations. The next operation is designed to remove the silver; this is effected by boiling in nitric acid, when the silver dissolves, leaving the gold in a finely divided state.

The "plant" used for this purpose consists of a number of large porcelain jars capable of holding about 35 gallons each.*

These are arranged in a double row and heated by steam pipes; they are inclosed in a chamber provided with sliding doors to prevent the escape of the noxious fumes, which are carried into a tall chimney from which they issue in a yellowish cloud. The dissolved silver is drawn off by means of a large siphon made of native California gold (valued at $3,000) and transferred to a vat made of wood (capacity 2,000 gallons), resembling those used in breweries. The vat contains several hundred gallons of salt water, and the silver is precipitated by the chlorine, a workman facilitating the operation by agitating the liquid with a large paddle provided with a long handle.

The precipitated silver is drawn off into large filters placed on trucks and thoroughly washed by running water until the test of litmus paper shows that all trace of acid has been removed. The chloride of silver now resembles pure white cottage cheese. It is transferred to another vat lined with lead. Zinc (which has been previously granulated by pouring while melted into cold water) is added to the silver, together with a little sulphuric acid; the chlorine deserts the silver for the baser metal, forming a soluble salt of zinc. The so-

*The charge for each jar is usually 190 pounds of granulations and 175 pounds strong nitric acid.

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lution is allowed to flow off, and the precipitated silver, after having been thoroughly washed, is pressed into round cakes called "cheeses," dried in an oven and melted in the furnace ; it is finally cast into a bar, and is found to be uncontaminated with its former base associates, being usually 998 to 999 fine.

The gold which remained in the porcelain jars is in the form of fine powder, and resembles sifted gravel.

After thorough washing to remove the silver nitrate the gold sediment is placed in cast-iron pots and boiled in strong sulphuric acid with a little niter added ; it is then washed, dried, pressed into cakes and melted. The bars are nearly pure gold, about 999 fine.

All that now remains for the melter and refiner to do is to weigh out the requisite amount of copper to form the coin standard, which is 9 parts of gold or silver (as the case may be) and 1 part base metal. In other words, our coin standard is nine-tenths fine.

The alloy is melted in large crucibles made of plumbago, holding over 6,000 ounces, and constantly stirred to render the mass homogeneous. The standard metal is cast into flat bars called ingots, 12 inches long, ½ inch thick, and from ¾ to 1½ inches wide ; the ingots are filed to remove the ragged edges, and the rough tops cut off with large steam shears. Two samples from each melt are assayed, and if the ingots are found to be of the proper fineness and of uniform composition, they are delivered to the coiner.

*The Mechanical Processes.*—The coiner transfers the ingots to the rolling mill, and when they have been sufficiently laminated by successive rolling and annealing, the strips are passed through a machine called the "draw bench," for the purpose of reducing them to the exact thickness required for the coin. This operation is similar in principle to wire drawing, and consists simply in squeezing the flat strips of metal between two stationary steel cylinders set to the desired gauge. The strips are now passed to the cutting press, which consists essentially of a round punch, the size of the "planchet," or blank required for the coin, working up and down very rapidly into a hole on the steel bed plate.

The strips are passed by hand through the press, and the blanks fall into a box below. The unused portion of the strips or "clippings," is returned to the melter and refiner and remelted. The planchets are next taken to the "adjusting room," where may be seen a number of ladies seated at a long table, each one provided with a little balance and a file. Each lady is supplied with a pile of planchets, and she proceeds very deftly to weigh each one against a properly adjusted counter-weight. The planchets that are too light are thrown into a separate pile and returned to the melter and refiner, to be remelted with the clippings, while those that are too heavy are adjusted by filing on the edge. Some years ago a novel automatic adjusting machine, designed by Mr. Ludwig Seyss, of Vienna, was introduced for the purpose of facilitating the work and diminishing the necessity of hand labor. It is an exceedingly beautiful and ingenious piece of mechanism, but is too complicated to admit of an intelligible description without the aid of sectional drawings. A description of this instrument will be found in the *Journal of the Franklin Institute*, of February, 1878. It not only weighs the blanks automatically, but also separates them into three kinds ; those that are too heavy falling into one box, the light ones into another, and those of the right weight

into a third. The machine will weigh and assort as many pieces in an hour as five expert ladies can by hand, but when we consider that there are ten balances in the machine, engaged in weighing at the same time, and only five used by the ladies, they must be awarded the palm for expedition.

The machine also requires the constant attention of one person to supply the blanks or planchets, and frequent attention of the expert adjuster of balances. When the additional cost of steam power and wear and tear of the parts is added to the original cost of the apparatus, its merit from an economical point of view is not so great as would at first sight appear.

The next operation to which the blank pieces are subjected is to impart the raised edge, technically called "milling."

The machine used for this purpose is an American invention, and is admirable for its simplicity as well as for the rapidity with which it accomplishes the work.

The blanks are fed by an attendant into a tube, and they are drawn horizontally, in single file, through a gradually narrowing channel formed by a groove in the periphery of a rapidly revolving disk on one side, and a stationary segment of corresponding curve on the other, keyed a little closer to the wheel at one end. The blanks are in this way compressed on the rim, acquiring the "milled edge." This machine is capable of milling as many as 1,200 pieces per minute.

The blanks are now taken to the pickling vats, where they are immersed for a couple of minutes in weak sulphuric acid for the purpose of removing the black oxide of copper; they are then washed in pure water and placed in a rotating cage filled with sawdust. This rapidly dries the blanks, and when removed to the coining room they have acquired a fine surface.

*The Coining.*—The early methods of coining were exceedingly crude and imperfect. The metal was hammered into a thin plate; pieces of irregular size were cut out and beaten into a bullet shape; this bullet was placed on a sort of anvil having the reverse die cut upon its face.

The obverse die was held in the hand like a punch, and by the aid of a heavy hammer the bullet was flattened out and coined at the same time.

There are many interesting specimens of this antique coinage to be seen in the Mint cabinet. The oldest are to be found in the case devoted to coins of the Greek Republic, dating back to seven centuries before the Christian era. It was not until the middle of the sixteenth century that the forge and hammer were succeeded by more scientific methods.

Formerly coins were struck in presses worked by a screw; but we adopted, many years ago, the admirable invention of a Frenchman, named Thenolliér, which has been further improved upon by the skill of a former coiner, the late Mr. Franklin Peale. This machine operates on the mechanical principle of the "toggle joint" (of which the elbow-joint is a familiar example). It is controlled by a lady who feeds it with the blanks, which she places in a vertical tube. A pair of "feeders" catch the bottom piece and carry it forward, where it rests in the "collar" between the upper and lower dies; the lever is now descending with the upper die while the lower die remains fixed; the pressure increases with perfect uniformity up to the maximum, which is equivalent to about 10 tons for the dime, 80 tons for the double eagle and 120 tons for the silver dollar. The pressure gradually decreases again by reason

of the relaxation of the upper joint, the lower die pushes the piece out of the collar into which it has expanded, and from which it acquires the "reeded edge." Meanwhile, the feeders have provided another blank, and as they bring it forward they push the coined piece into a channel, through which it slides into a box beneath the machine. The coins are then inspected by the foreman, and any cracked or defective pieces set aside.

The larger denominations of coin are counted by hand, and the smaller pieces, as well as the "bronze" and "nickels," are numbered by means of a simple and ingenious arrangement called the counting board

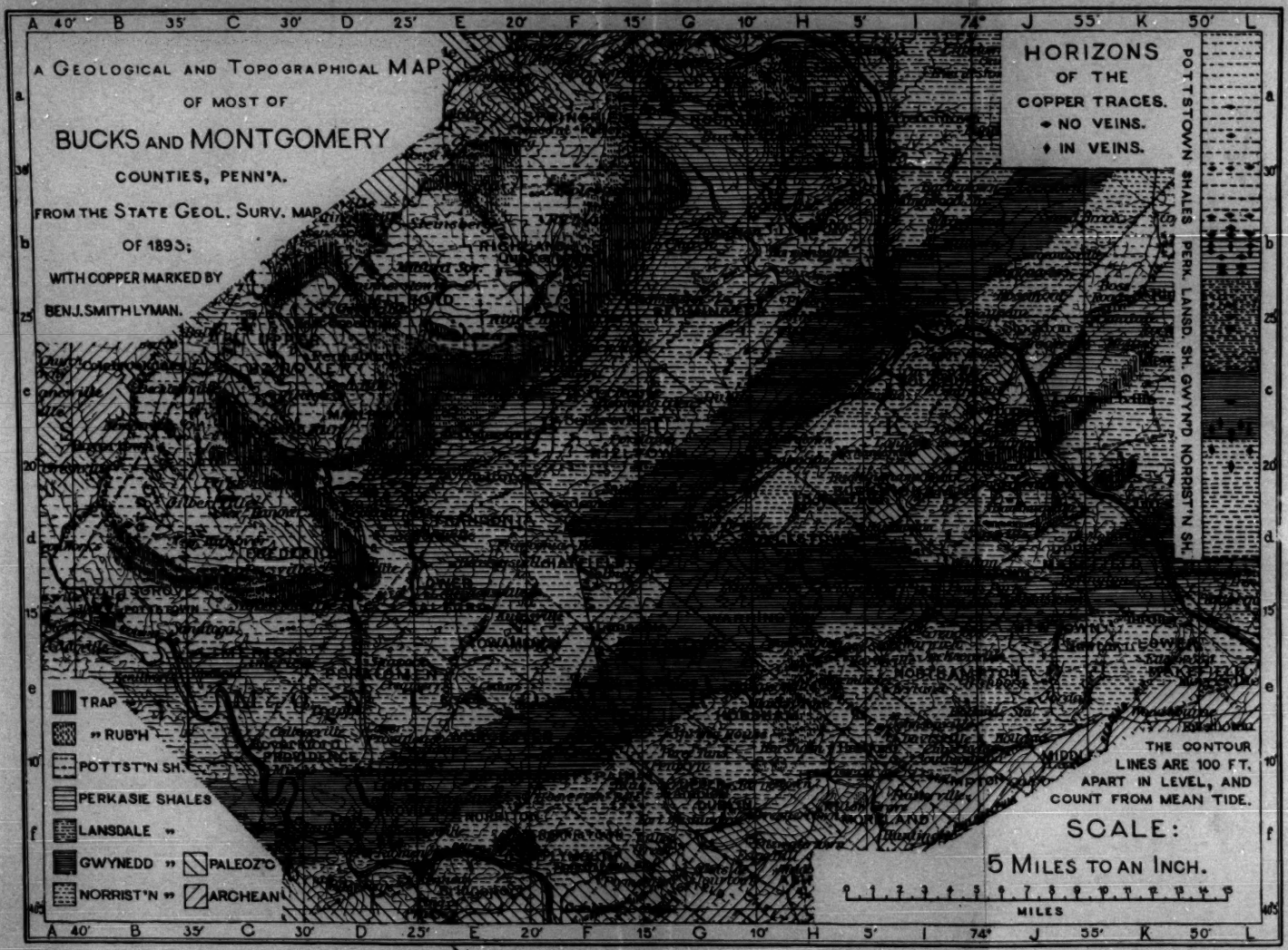
After the coins have thus been counted and weighed, they are tied up in linen bags and delivered to the treasurer in drafts of $5,000 each. The accuracy of the adjustment of the weight is so nice that there is rarely a deviation from the true standard weight of as much as $\frac{1}{100}$ of an ounce in any delivery of either gold or silver coin.

As a final precaution, the assayer is required by law to select at random one coin from every lot of $20,000; these are sealed in envelopes, numbered, and placed in a strong box provided with two locks; the key of one is kept by the treasurer and the other by the assayer. These sample pieces are called the "pyx." They remain sealed until the Commissioners appointed, by the President assemble at the "annual assay" in February of each year to test their purity and weight; and it has rarely happened that any piece has been found to exceed the small limit of "tolerance" allowed by law.

The manufacture of the dies for coin requires a high order of artistic and mechanical labor, involving the talent of the designer and the skill of the engraver and sculptor. A detailed description of the processes involved would necessarily extend this paper beyond the limits assigned to it. A brief outline must, therefore, suffice. The artist first makes a free sketch on paper, he then models his design in wax upon a glass plate, and it is probably five times the size intended for the coin; from this he takes a cast in plaster, which serves, when coated with plumbago, as a matrix, from which an electrotype in copper is obtained. The electrotype, after being finished by hand, is used as the model from which the steel die is cut by means of a reducing pantographic cutting machine, somewhat similar to those used for reproducing designs for steel rolls used in making printed fabrics. A traveling pointer attached to the long arm of a lever is caused to move back and forth over all portions of the raised model, and a steel drill attached to the short arm is thus caused to cut the design in a block of steel corresponding in all its details to the model, but reduced to the proper diameter for the coin; the stars and lettering are now added, and the whole is finally touched up by the hand.

This design is called the "Hub" or "Master die;" from it the coining dies are made and reproduced in any number required. A block of steel having been softened by annealing, is placed in a screw press carrying the "hub," and by a succession of blows, followed by frequent annealings, the die from which the coin is to be made is produced.

It is possible (owing to the great value of the raw material) to bring the processes involved in our gold and silver coinage to a perfection which would not, perhaps, be found profitable in any ordinary industry; and this fact, together with the national pride which is felt in the matter, should offer encouragement to the invention of all practicable methods of producing perfect work and preventing losses.


A GEOLOGICAL AND TOPOGRAPHICAL MAP
OF MOST OF
BUCKS AND MONTGOMERY
COUNTIES, PENN'A.
FROM THE STATE GEOL. SURV. MAP
OF 1895;
WITH COPPER MARKED BY
BENJ. SMITH LYMAN.
HORIZONS
OF THE
COPPER TRACES.
NO VEINS.
IN VEINS.
POTTSTOWN SHALES
PERK. LANSD. SH. GWYN'D NORRIST'N SH.
TRAP
" RUB'H
POTTST'N SH.
PERKASIE SHALES
LANSDALE "
GWYNEDD "
NORRIST'N "
PALEOZ'C
ARCHEAN
THE CONTOUR
LINES ARE 100 FT.
APART IN LEVEL, AND
COUNT FROM MEAN TIDE.
SCALE:
5 MILES TO AN INCH.
MILES

*Stated Meeting, October 13, 1897.*

# COPPER TRACES IN BUCKS AND MONTGOMERY COUNTIES.

By Benj. Smith Lyman.

There are about thirty points in Bucks and Montgomery Counties where traces of copper ore have been found. Although it is workable at none of the places, it seems worth while that they should all be carefully recorded. The record, to be sure, is not so much to indicate where the most promising future search for ore might be made, as, rather, to prevent the waste of money in the useless digging and mining that the traces might occasion to the many men who are oversanguine in such matters and whose hopes and judgment are so apt to be led astray by the slightest evidence of hidden underground wealth. Indeed, in many cases, one of the most important objects and benefits of a geological survey is the saving of the immense sums of money that are constantly thrown recklessly away on account of the lack of a cool consideration of the facts in the light of well-established geological principles. In these two counties themselves money has time and again been wasted in the fruitless digging for coal and copper where it would have taken but little geological skill to foresee the inevitable result. Still, something useful can be learned from these unsuccessful attempts, and the observations of the copper traces, small and intrinsically worthless as they are, may yet throw some valuable light upon the laws of the deposition of copper ore.

## PLACES AND HORIZONS.

It will be well, first, to identify the points where the copper traces occur, both geographically, with the help of our little map, showing at the same time the limits of the different geological subdivisions of rock-beds, and also strati-

graphically, with a small general columnar section of the same sets of beds.

The accompanying map shows in general precisely enough the place of each occurrence of traces of copper, and it is further chiefly necessary to indicate for each the rock-layer that contains the traces.

Each place is designated by three letters. The first letter indicates the five-minute space of longitude, as marked on the border of the map. The second letter indicates in like manner the latitude. The third letter is the one the place had on a certain page in the field note-book, and is marked on the map. Where necessary, in order to distinguish two places having the same letter, the number of the note-book page is given, at least the last digit. The places will be mentioned in the order of their geological horizons, beginning at the top.

POTTSTOWN SHALES.

*Bda.*—Roadside, 1½ miles south of Gilbertsville; malachite traces in 2½ feet of grayish-red sandy shales, with mustard-seed pebbles, below 2½ feet of grayish-red and green mottled hard shales.

*Cdz.*—Northern roadside, 3 miles east of Gilbertsville; malachite traces in 5 feet of dark, dull red, sandy, hard shales.

*Bdp.*—Roadside, ⅛ mile north of northern edge of Pottstown; malachite traces in 4½ feet of grayish-green hard shales, a few yards north of two exposures of red shales.

*Bdu.*—James Gilbert's copper place, northwest edge of Pottstown; malachite traces in greenish-gray traces of old rubbish thrown out from a hole, now filled up, said to have been about 10 feet deep.

*Bdl.*—Roadside, northern edge of Pottstown; malachite traces in 1 foot of grayish-green, rather soft weathered shales, under a foot of grayish, rather dark red shales.

*Dcv.*—Roadside, east edge of Pennsburg; malachite traces in a foot of grayish-green hard shales with black specks, below about 16 feet of red shales, and above some 50 feet of red shales.

*Ddh.*—East bank of the Perkiomen, opposite Schwenksville; malachite specks in 1½ feet of reddish-gray hard shale, below 1 foot hidden, under 6 inches grayish green, hard shales at the top of long exposure, a few yards below an old abandoned quarry.

*Dda* and *b.*—Roadside, ½ mile east of Schwenksville, and east of the Perkiomen; malachite traces in 4-foot exposure of greenish- and reddish-gray hard shales with white specks. A hole formerly dug on each side of the road, both on the same bed, but with more malachite traces on the north side.

*Fbe.*—The Bunker Hill cut, on the North Pennsylvania Railroad, 2 miles southeast of Quakertown; malachite traces in 6 feet of greenish-gray hard shales, 160 feet, geologically, above the bottom of the section of the cutting, and below 4 feet of dark greenish-gray hard shales, and that below 60 feet of red shales, under 20 feet of trap, which is 234 feet below the top of the exposed section.

*Ddo.*—On the Perkiomen Railroad, half way between Hendricks' and Kratz Stations; malachite traces and pyrites specks in 6 inches of grayish-green, rather soft shales, below 53 feet and above 25 feet of red shales.

*Ddr.*—On the Perkiomen Railroad, 200 yards north of *Ddo;* and apparently the same bed, traces of malachite.

*Jcj.*—Roadside, 1¼ miles west of New Hope; malachite thin films in a 4-inch layer of dark gray, weathering bright green hard shales, below 13 feet and above 15 feet of red shales.

PERKASIE SHALES.

*Ddd.*— A. Charles's first trial hole, in the field east of his house, ½ mile to the east of *Ddb;* about 1883. He says he found copper traces, but the hole is now all fallen in.

*Ddb.*—A. Charles's copper place, ½ mile south of Sumneytown; malachite traces and copper pyrites traces in a 7-inch vertical vein of clay and quartz in dark reddish-gray, calcareous very hard shale. Dug a little in 1885, but mainly in 1889, an open cut, perhaps 20 yards long by 4 yards wide, dug horizontally into the hillside. In the old rubbish specks

of copper pyrites are seen in hard, dark red shales, with rather more hematite.

*Ddl.*—Roadside, 1 mile east of Sumneytown, copper traces in ½ foot of dark reddish- and greenish-gray very hard shales, below some 7 feet of hidden, under 2 feet of dark reddish-gray hard shales.

*Gay.*—Roadside, just above, south of, Kintnersville, malachite traces at the bottom of 4 feet of grayish-green shales below 14 feet and above 10 feet of red shales.

*Ddi.*—A. Kober's copper place, 1 mile southeast of Sumneytown, and halfway between *Ddb* and *Dde*. Specimens of malachite, copper pyrites and azurite with calcite, thrown out here from a now inaccessible shaft said to be about 40 feet deep, and another, a dozen yards northeast "about 24 feet deep;" also a hole a dozen yards southwest of the first, said to be "50 feet deep." The vein is said to be 2 feet wide. A hole 9 feet deep, perhaps 100 yards to the south, has malachite traces in 9 feet of dark reddish- and greenish-gray very hard shales.

*Dde.*—On a crossroad, 1 mile east of *Ddb*, and 1½ miles east of Sumneytown; malachite traces in a foot of dark reddish-gray hard shales, and in ½ foot of the same, the two layers separated by unexposed layers.

*Ga6p.*—East side of road, at the north edge of Nockamixon village; malachite traces in 1 foot of grayish-green shales, below 5 feet of red shales at the top of the exposure.

*Fcl.*—Roadside, 1½ miles south of Keelersville; malachite traces and pyrites in 1½ feet of grayish-green hard shales, below 1½ feet and above 2 feet of red shales.

*Ga5p.*—Roadside, ¾ mile southeast of Bursonville, minute specks of copper pyrites in 2 feet of grayish-green hard sandy shales, with some minute white quartz pebbles, below 1 foot of lighter grayish-green pebbly shales, and above some 3 feet of hidden, above 2 feet of red shales, at the bottom of long exposures.

*Edw.*—Roadside quarry, 1½ miles east of Lederachsville; malachite traces in about 3 feet of green, hard shales, below about 8 feet of dark red, hard shales and above about 12 feet of reddish, dark gray, hard shales.

*Haa.*—Jacob Tettemer's copper place, 1 mile west of Uhlertown, a hole, now full of water, originally dug, it is said, 20 or 30 feet deep, about 1875, by Mr. Culmer, of Easton. Green malachite traces were found, such as are now to be seen among the shale bits in the cornfield around the hole.

LANSDALE SHALES.

*Fda.*—Roadside, 1¼ miles northeast of Kulpsville; bright malachite seams in 1 foot of green shales, below about 14 feet of red sandy shales, and above about 9 feet of like shales.

*Iag.*—Southeast side of Copper Creek, 1½ miles south of Frenchtown, N. J.; green malachite traces in 1 foot of green shales, below 6 inches of red shales exposed. A hole, said to be 20 or 30 feet deep, was dug here, on Mr. Hinkle's land, about 1883, and one on the opposite side of the creek, on Mr. Edgar Lance's land, said to be similar, with the green shale 3 feet thick. It is said one of the operators of the Flemington copper mine, abandoned some years ago, made the Lance opening, and pronounced the ore the same as theirs, but insufficient to work. Both holes were fallen in or full of water in 1889.

*Def.*—At the Collegeville quarry, ¾ mile north of Collegeville. The 13 feet of rather hard and shaly fine red sand rock at the bottom of the quarry, in 1889, underlying about 15 feet of green shales, has malachite traces and little holes, perhaps from the weathering out of pyrites. It is said about 6 inches of coal were found in the quarry, and it was burnt in the forge.

GWYNEDD SHALES.

*Dfa.*—On Dr. J. W. Griffith's farm, near the mouth of Skippack Creek, in Lower Providence Township, a piece of malachite was ploughed up in 1865; and it was afterwards sold by A. E. Griffith to the Mineralogical and Geological Section of the Academy of Natural Sciences. (Kindly communicated by Theo. D. Rand, Esq., Director of the Section.)

*Gdt.*—The abandoned New Galena mine, 3¼ miles northwest of Doylestown, full of water and inaccessible in 1889, but said to be 100 feet deep. Pieces of ore lying about contained specks of copper pyrites and traces of malachite, along with a little galena, a little zinc blende and much quartz. The country rock was apparently a blackish-gray hard shale. The mine appears to have been repeatedly tried for thirty-five years past.

*Cfb.*—The map, at p. 675, of Vol. II, of Rogers' Final Report, 1858, shows the Morris copper lode ½ mile south of Phœnixville. It was long since abandoned.

*Efw.*—Two miles northwest of Norristown and 1 mile east of Fairview. The occupant of the house near by says, 11th May, 1889, that in the field just below the house there is a well from which copper specimens were dug many years ago. But his father would not allow some desirous Philadelphia party to dig further.

*Dfd.*—Perkiomen Lead and Copper Mines, ⅝ mile northwest of Shannonville; a little copper pyrites and malachite traces in the rubbish (also azurite according to Dana) at the now inaccessible mines abandoned about 1868 and begun some twenty years earlier. The country rock appears to be a rather reddish-gray coarse sandrock. In the rubbish there was found with the copper, much quartz, but no blende nor galena.

*Dfh.*—Ecton Mines, ½ mile west of Shannonville. Mere traces of copper pyrites, with blende and galena in the rubbish of the old abandoned mines, apparently of the same date as the Perkiomen Lead and Copper Mines. The country rock appears also to be essentially the same, a light, reddish-gray, rather coarse sandrock; but is possibly a dark, reddish-gray, coarse, rather sandy micaceous shale.

*Cfc.*—The Shannonville copper lode, at Shannonville, marked on the map, at p. 675, of Vol. II, of Rogers' Report of 1858. Long ago abandoned.

NORRISTOWN SHALES.

*Cfw.*—The abandoned, inaccessible Phœnixville Mines (the Wheatley, Brookdale, Chester County, Napoleon and

Petherick's Lead Mines), at the edge of the New Red, 1½ miles south of Phœnixville. Dana mentions as occurring here: chalcopyrite, native copper, malachite, azurite, indigo copper, black oxide of copper, phosphocalcite, as well as galena, blende and other lead and zinc ores, quartz, fluorite and a number of other minerals. Rogers (Final Report, 1858) enumerates some thirty minerals found in these mines. He points out that the veins within the New Red are characterized by containing ores of copper, while those within the gneiss bear lead as their principal metal, and zinc ores occur in both sets of lodes, but rather more in the copper lodes.

*Dfd.*—The Port Kennedy copper lode, at the village of that name, is marked on the map, at p. 675, Vol. II, of Rogers' Report of 1858. It must have been abandoned very long ago.

MODE OF OCCURRENCE.

At Charles's copper place (*Ddb*) the copper ore occurs in a very narrow vein, cutting across the rockbed, and the ore seems to occur in a like manner at Kober's copper place (*Ddi*), at New Galena (*Gdt*), and at the Perkiomen (*Dfd*), Ecton (*Dfh*) and Phœnixville (*Cfw*) Mines, and at Shannonville and Port Kennedy; but at the twenty-seven other places the copper ore appears to be disseminated in small particles through the rockbeds without any perceptible vein. The columnar section, with the horizons of the copper traces marked in, makes it obvious that they occur most numerously in and near the Perkasie shales and the lower part of the Gwynedd shales. It is also clear that in a few cases the same horizon has been found to bear traces of copper at more than one distant point. The striking feature of the grouping of the copper-bearing horizons is that they occur principally in or near those two sets of shales that contain black or dark-colored beds. The explanation readily suggests itself that carbonaceous matter has by reduction produced copper sulphide from copper sulphate that was in the water from which the shales were deposited, or by which they were permeated from below

through the few narrow fissures observed, or otherwise. The copper sulphide may, by the oxidation and carbonating of weathering, have produced the malachite so frequently observed on the outcrop. This deposition of the copper from solution through precipitation by the carbon of organic matter agrees well with the most reasonable explanation of the occurrence of copper ore in the permian beds of the Mansfeld, of Texas and of Nova Scotia (see E. J. Schmitz, Trans. Am. Inst. M'g Eng'rs, Vol. XXVI, p. 97, and H. Louis, same volume, p. 1057, 1897). The somewhat prevalent greenish color of the Perkasie shales, as well as the dark-gray color common in the lower part of the Gwynedd shales, would also be generally, and apparently with perfect reason, attributed to the agency of organic matter that has reduced the red peroxide of iron so strongly coloring the greatly predominant red shales of the rest of the New Red, and has given rise to the gray, green or blue salts of the protoxide of iron. The several copper horizons outside of those two comparatively dark sets of shales may likewise occur in connection with somewhat more isolated greenish or dark shale beds; for darker or greenish beds do occur here and there among the prevalent red ones. Even if the copper traces be found within red beds, as they appear to be in some cases, the reduction and precipitation may have been caused by organic matter, either present in those very beds or in adjacent darker or more greenish beds, acting upon the waters soaking through the different layers. In some cases it may have been single, scattered plants that have caused the precipitation of the copper, without the power to affect the color of the main body of the shale bed.

It appears then that the mere traces of copper in Bucks and Montgomery Counties, wholly unworkable as they are, yet have some use in indicating by their mode of occurrence the origin of many copper ores, corroborating what has been inferred from the deposits of the Mansfeld, Texas, Nova Scotia and elsewhere.

# ELECTRICAL SECTION.

*Stated Meeting, October 24, 1898.*

## THERMO-ELECTRIC AND GALVANIC ACTIONS COMPARED.

By Charles J. Reed.

In addition to the methods necessitating mechanical motion, I believe there are at the present time recognized two other distinct processes of generating an electric current. These processes are the electro-chemical and the thermo-electric. While these two processes are of an entirely different nature, it appears that the electro-chemical or electrolytic process can never take place without being accompanied and modified to some extent by the thermo-electric process. The thermo-electric process may in a certain kind of apparatus take place without any chemical or electrolytic reaction. In another kind of apparatus the thermo-electric process is always accompanied and its results modified by chemical change. This concurrence of the two processes, which is entirely accidental and due to the nature of the materials constituting the apparatus, has in some cases given rise to a difference of opinion as to whether the action in a particular case is electro-chemical or thermo-electric.

It is on account of this difference of opinion, which I believe should not exist, that your attention is asked this evening to the consideration of certain thermo-electric and certain galvanic actions that have been subject to this confusion.

In order to discuss these actions intelligently, it is necessary to define at the outset exactly what is meant by galvanic and by thermo-electric action, and to indicate the general characters by which it has been customary to distinguish them.

We shall use the term *thermo-electric*, to include any process by which external heat is continuously absorbed directly into a closed circuit and simultaneously evolved as electrical energy in that circuit, that is, any process in which the electrical energy comes entirely from the external heat by direct absorption and in which there is no limit to the quantity of heat that may be transformed.

The term *galvanic*, we shall use to designate only that process, by which the energy liberated in a chemical change is evolved as electrical energy and in which chemical change is the only source of the energy. The source of energy is not external to the circuit, but solely in the chemical energy of the materials constituting the circuit. Any electrical energy evolved by galvanic action must leave the circuit with less potential energy in its final state than it had at the beginning and must be limited in quantity to the available energy of chemical reaction in the materials constituting the circuit. The distinction to be kept clearly in mind between the processes is that in one case the source is external to the circuit, while in the other it is internal.

The opinion has recently been advanced by Mr. C. P. Steinmetz that chemical action may continue to evolve electrical energy indefinitely, provided heat or some other form of energy is simultaneously applied to regenerate the chemical energy and thus maintain the materials in their initial state. This supposition is not only incapable of experimental proof, but seems to have no particular significance, if true. To say that a revolving shaft, which receives motion from an engine and transmits it by means of gears and belts to other machinery, evolves energy or is, in the sense we are considering, the source of energy, is absurd, and the assertion is not justified by the saying the motion of the shaft is continually regenerated by the engine, so that its final and initial states are identical. The shaft can evidently impart only the energy it has previously absorbed from the engine. If it were a source of any of the energy, it would have power to at least start the motion and continue it for a short time without the help of the engine. For the same reason a body or system cannot evolve energy

by a chemical change originating within the system, which requires simultaneous and continuous reversal by the absorption of an equivalent external energy, and which leaves the initial and final chemical states identical.

I shall premise, therefore, that no body or system can be the origin or source of energy or of any process evolving energy, unless in its final state its energy is less than in its initial state. If we accept this premise, we establish a criterion, by which the distinction between galvanic and thermo-electric action may be invariably made.

It is not necessary this evening to trace the progress and history of the laws governing these processes, which have been brought to light during the past three-quarters of a century, from Seebeck and Faraday to Kelvin and Tait. It

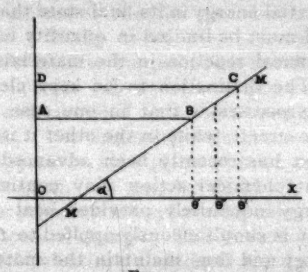



FIG. 1.

will be sufficient for our purpose to keep before us a few of the most important of these laws.

*Thermo-electric Action.*—With reference to thermo-electric action there are recognized two distinct processes or kinds of transformation, known as the Peltier effect and the Thomson (Kelvin) effect. The various thermo-electric effects due to irregularities in the structure or molecular condition of the bodies experimented upon, such as have been pointed out by Magnus, Kelvin and Le Roux, all come under the Peltier and Thomson effects.

Kelvin found that a positive current in an unequally heated iron conductor evolves heat in passing from a colder to a hotter part of the conductor and absorbs heat under

the same conditions in a copper conductor, and, conversely, that, in passing from a hotter to a colder portion, these actions are reversed. Professor Tait showed experimentally that the coefficient of this effect is proportional to the mean absolute temperature. If a curve be drawn, whose abscissa is the absolute temperature and ordinate, the thermo-electric power of a metal with respect to lead (in which the Thomson effect appears to be zero), the curve is found to be a straight line.

*Fig. 1* shows Tait's diagram of thermo-electric power. The tangent of the angle, $\alpha$, which the curve of thermo-electric power, $MM$, of any metal with respect to lead makes with the axis, $OX$, is the coefficient of the Thomson

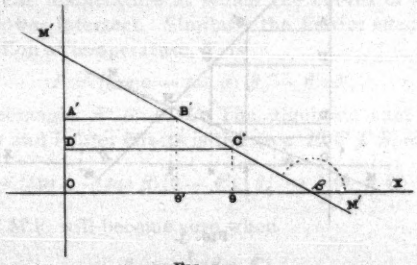



FIG. 2.

effect in that metal. The Thomson effect in the metal, if its terminals are at the temperatures, $\theta$ and $\theta'$, is the area, $ABCD$. It will be seen that this area is, for a given difference of temperature, proportional to the mean absolute temperature, $\theta''$, and for a given mean absolute temperature, is proportional to the difference of temperature between its terminals. That is, the area representing this effect is the rectangle of the mean absolute temperature and the difference of temperature into the tangent of the angle, $\alpha$.

In *Fig. 2* $\tan \beta$ is negative, and the Thomson effect, $A'B'C'D'$, is in the opposite direction.

*Fig. 3* shows the diagram of the junction of two conductors, whose curves of thermo-electric power are $MM$ and

$M'M'$, whose junction is at temperature, $\theta_o$, and free ends at temperature, $\theta'$. Here the electromotive force due to the Thomson effect in the two metals is the sum of the areas, $ABCD$ and $A'B'C'D'$, and both tend to produce a current in the same direction in the circuit.

The Peltier effect, another kind of thermo-electric inversion, unlike the Thomson effect, does not occur in a single conductor, but at the junction of two dissimilar conductors. Peltier discovered that when an electric current crosses the junction of two conductors in one direction the

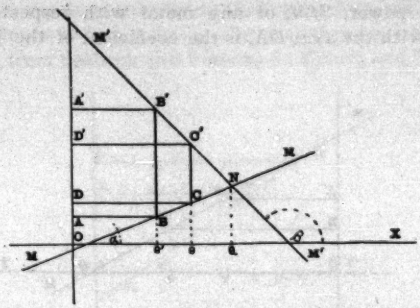



FIG. 3.

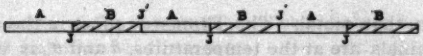



FIG. 4.

junction is heated and when it crosses in the opposite direction the junction is cooled. This is the inverse of the effect discovered by Seebeck, the development of electromotive force in one direction when the junction is heated and in the opposite direction when it is cooled.

*Fig. 4* represents a series of similar conductors, $A$, of one substance, joined by similar alternate conductors, $B$, of another substance. Assume that a current in passing through this series from $B$ to $A$ across the junctions, $J$, causes those junctions to be cooled. An electromotive force tending to

increase the current is developed at $J$, while at $J'$ heat is evolved and a counter electromotive force developed. If the junctions, $J$ and $J'$, be maintained at the same temperature, the absorption at $J$ equals the evolution of heat at $J'$, and the Peltier effects balance each other. At the same time there could be no Thomson effect in either conductor. The electromotive force is always the algebraic sum of the Thomson and Peltier effects, and is well shown in Tait's diagram.

Referring again to *Fig. 3*, Kelvin and Tait have shown that the Peltier effect of a hot junction at temperature, $\theta$, is the rectangle, $D'\ C'\ D\ C$, or

$$P = (tan\ a - tan\ \beta)\ (\theta_0 - \theta)\ \theta \qquad (1)$$

$\theta_0$ being the temperature at which the curves of thermo-electric power intersect. Similarly the Peltier effect at the cold junction at temperature, $\theta'$, is

$$P = (tan\ a - tan\ \beta)\ (\theta_0 - \theta')\ \theta',$$

or the rectangle, $A'\ B'\ B\ A$. The algebraic sum of the Thomson and Peltier effects is the area, $B'\ C'\ C\ B$, or

$$E. = (tan\ a - tan\ \beta)\ (\theta - \theta') \left[\theta_0 - \frac{1}{2}(\theta + \theta')\right] \qquad (2)$$

The E.M.F. will become zero when

$$\theta_0 = \frac{1}{2}(\theta + \theta'),$$

that is, when the mean temperature of the junctions is $\theta_0$, as shown in *Fig. 5*. On this account $\theta_0$ is called the "neutral point."

It is evident that the E.M.F. may also be expressed in terms of $P$ and $P'$, the Peltier effects per unit of current per unit of time at the hot and cold junctions respectively, since

$$E. = \frac{1}{2}(B\,B' + C\,C')(\theta - \theta') = \frac{1}{2}\left(\frac{P'}{\theta'} + \frac{P}{\theta}\right)(\theta - \theta')$$

When $\theta' = \theta_0$ we have, collecting constants,

$$K\,E = \frac{\theta - \theta'}{\theta}$$

As this is also the expression for the maximum efficiency of any thermo-dynamic transformation, it follows that under no circumstances can the efficiency of a thermo-electric apparatus be greater than when either the hot or the cold junction is maintained at the neutral point. With one of the junctions at the neutral point we see from (2) that the electromotive force is proportional to the square of the difference in temperature between the junctions, or

$$E = -\frac{1}{2}(tan\ \beta - tan\ \alpha)(\theta - \theta')^2$$

In *Fig. 5* the electromotive force is the area of the triangle, $C\ C'\ N$, which is evidently proportional to the square of its altitude $\theta - \theta'$.

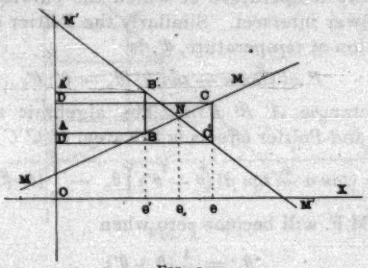



FIG. 5.

The experiments of Kelvin and Tait, on which these conclusions are founded, were confined to metals and alloys, but there is no reason for supposing that these effects exist only in metallic conductors. The same reasoning, which led Kelvin to the prediction of the Thomson effect in metallic conductors, requires also the existence of both of these effects in any conductor, in which one of the effects is possible. The existence of these effects in electrolytes has been conclusively established by Bouty and others.

*Galvanic Action.*—Galvanic action may be considered to be identical with electrolysis. It is merely a particular case of electrolysis, in which the chemical change evolves energy, whereas, what we ordinarily call electrolysis re-

quires external energy to produce the chemical change. This may be expressed by saying that electro-chemical action is also a reversible effect or mode of transformation, and that when latent or chemical energy becomes electrical energy we call the action galvanic, but when the process is reversed and electrical energy becomes latent or chemical, we call the action electrolytic. Theoretically every galvanic action is reversible by an electric current in the opposite direction from an external source, and every electrolytic action is reversible as a galvanic action. This reversal, however, is not often practicable, because generally the products of the change in either direction are lost or become contaminated or enter into secondary reactions with extraneous substances. When this reversal is practicable and nearly perfect, the apparatus is called an accumulator or storage battery.

From this it will be seen that, while galvanic action always necessitates chemical change, chemical change is not always sufficient to produce galvanic action. Galvanic action always necessitates certain conditions, among which are the following:

(1) The chemical reagents concerned in an electro-chemical reaction must be electric conductors, and form part of the circuit in which the electrical energy is developed. A non-conductor, although intimately mixed or dissolved in the reagents can take no part in the reaction.

(2) At least one of the conductors must be a compound and an electrolyte. The reagents must disappear and the products of the reaction must appear at the terminals of this electrolyte; that is, at the points where the electric current enters and leaves the electrolyte.

(3) The chemical reaction must be exothermic, that is, must evolve energy.

A further condition seems to be that the electrolyte shall not be a single compound, but a solution of one compound in another.

The ordinary type of galvanic cell, shown in *Fig. 6*, consists of two solid conductors, *A* and *C*, connected by an electrolyte, *E*. In such an apparatus it is necessary that at

least one of the solid conductors shall be capable of acting chemically on the electrolyte.

A less common type of galvanic cell is shown in *Fig.* 7, consisting of two different electrolytes, *E* and *E'*, in contact with each other and also in contact with terminal conductors or electrodes, *e* and *e'*. In this type of cell the electrodes, *e* and *e'*, may be of the same material and both may be chemically inert to the electrolytes, but the electrolytes must be capable of acting chemically on each other.

There are two important laws governing electrolytic and galvanic action. One relates to the quantity of matter and the other to the quantity of energy concerned in the reaction. The first is known as Faraday's law of electro-chemical equivalents. It states that the quantity of electric cur-

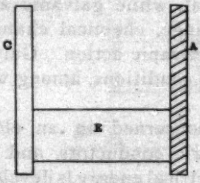



FIG. 6

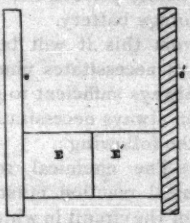



FIG. 7.

rent passing through a galvanic or electrolytic cell, which corresponds to a change of one unit of valence in a chemical equivalent of *one* substance, corresponds also to a change of one unit of valence in a chemical equivalent of *any* substance. This law was demonstrated experimentally by Faraday for very many substances, but it may also be deduced as a necessary consequence of the atomic theory and the theory of the conservation of energy.

Of equal importance is the law governing the electromotive force of an electro-chemical reaction. It was deduced from Faraday's law and the principle of conservation by Kelvin and published by him in 1851. It states that the electromotive force of any electro-chemical reaction is, in absolute measure, equal to the dynamical equivalent of the

chemical action that takes place during the passage of a unit current for a unit of time.

I have taken the time to rehearse these general statements in regard to thermo-electric and galvanic action, in order that you may not mistake my premises and that you may at the same time have clearly in mind the criterion I shall use in determining whether a reaction is galvanic or thermo-electric.

When a system spontaneously undergoes a chemical change evolving electrical energy without the application of external heat, and by the mere juxtaposition of its parts or elements, there can be no doubt that the energy is evolved as a result of the chemical change, and that, if no heat is allowed during the process to enter or leave the system and no change of temperature occurs within the system, chemical action is the *only* source of the energy. The chemical energy of the system will in this case be less in the final than in the initial state.

When, on the other hand, electrical energy is evolved only during the application of external heat, and when the chemical state at the beginning is identical with the chemical state at any succeeding period, the electrical energy must come solely from the heat absorbed directly into the circuit during its action and the process is thermo-electric.

The initial and final chemical states may be different and yet the process be entirely thermo-electric. This evidently occurs whenever, by the application of heat, electrical energy is evolved and the final chemical state is one of greater chemical or potential energy than the initial. Here the heat energy transformed must equal the electrical energy evolved plus the chemical energy stored or accumulated. The storing of the chemical energy may be due to a separate thermo-chemical process accompanying the thermo-electric process, or it may be due to an electrolytic action resulting from the passage of the thermo-electric current through the materials constituting the closed circuit.

When by the application of external heat a chemical change occurs, evolving electrical energy in excess of the energy available from the chemical reaction and also in

excess of the energy absorbed as heat, the electromotive force of the circuit is always the sum of the thermo-electromotive force added to the electromotive force of the electrochemical reaction, and the transformation is the result of the simultaneous action of both processes.

When a chemical change in a system results in the evolution of electrical energy and heat (exclusive of incidental losses, such as the heat due to the Joule effect), the difference between the chemical energy of the initial and final states is equal to the electrical energy plus the heat evolved by thermo-electric inversion.

The necessary concurrence of thermo-electric action with all cases of galvanic action may be predicted from the nature of the apparatus.

*Fig. 8* represents diagrammatically the apparatus required for thermo-electric action. It consists of two con-

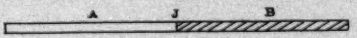



FIG. 8.

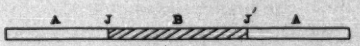



FIG. 9.

ductors, *A* and *B*, of different substances (or one substance in two different molecular states), electrically united at a point called the junction. *Fig. 9* represents diagrammatically the apparatus required for galvanic action, and consists of at least three conductors of different kinds electrically connected in series, of which at least one, *B*, must, as previously stated, be an electrolyte. It is evident from an inspection of these diagrams that the apparatus necessary for galvanic action always includes the apparatus necessary for thermo-electric action, that is, one or more junctions of dissimilar conductors; and that a galvanic current cannot flow through such an apparatus without causing thermo-electric inversion, both at the junctions and throughout the mass of the several conductors. We have reason to believe, therefore, that no galvanic battery of any form can give an

electric current without that current being affected to some extent by thermo-electric action within the cell. This action may result in an increased or a diminished electromotive force, or possibly an increase in certain parts of the cell and an equal decrease in other parts. It has also been shown by Helmholtz that the formula for the electromotive force of an electro-chemical reaction, as stated by Kelvin, requires a correction due to the change of entropy the system undergoes, which necessitates that the system shall during action either undergo a change of temperature or absorb or evolve heat in accordance with the formula for thermo-electric inversion, as expressed in terms of the Peltier effect.

It has sometimes been supposed that a galvanic battery may be constituted of less than three different substances. That this is impossible is evident from *Fig. 10*, which repre-

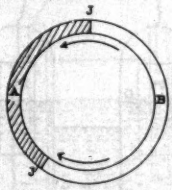



FIG. 10.

sents such a circuit in the form of a closed ring of uniform temperature, made up of two conductors, $A$ and $B$, joined at the points, $J$ and $J'$, one being an electrolyte. Galvanic action must originate in a chemical change between the conductors constituting the circuit, that is, between $A$ and $B$, and must take place at the terminals of the electrolyte, $J$ and $J'$. But the chemical conditions must be different at these two points, which is contrary to the supposition that there are only two substances. Let us assume that at $J$ a chemical change occurs producing an E.M.F. tending to send a current in the direction, $J\,A$, indicated by the arrow at the top of the diagram. By hypothesis the chemical conditions at $J'$ are identical with those at $J$, and there is also an E.M.F. at $J'$ tending to send a current in the direction, $J'\,A$, indi-

cated by the arrow at the bottom. These two electromotive forces, being equal and opposite, can result in no current. On heating or cooling either $J$ or $J'$, we invariably get a current by thermo-electric inversion. The fact that certain thermo-electric couples of this form, in which one conductor is an electrolyte, give a very high E.M.F., has led to the belief that the current is due to chemical action and that the heat merely enables the chemical action to take place. But it is evident that any electro-chemical change which may occur at $J$, causing a current to flow around the ring in either direction, must be electrolytically reversed at $J'$ with an absorption of the same amount of energy as that evolved at $J$. Any electrical energy evolved from such an

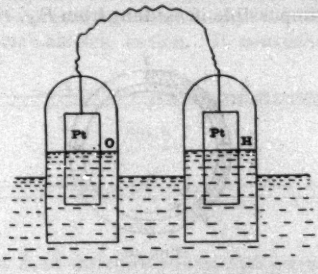



FIG. 11.

arrangement must, therefore, originate in the heat applied and not in the chemical change. To deny this, is to deny that a result originates in its cause. The cause of the electrical energy is the heat applied, and the quantity is equivalent to the heat absorbed.

There are some deceptive cases, in which galvanic action apparently results from the juxtaposition of only two conductors, but this is only apparent. We may cite as an example of this kind the so-called gas battery, in which two platinum plates are immersed in dilute sulphuric acid, one of the plates being surrounded by hydrogen gas and the other by oxygen, as shown in *Fig. 11*. In this battery, which gives an electromotive force of about one volt, the circuit

consists apparently of nothing but platinum and the dilute acid, but in reality it consists of a compound of hydrogen and platinum and a compound of oxygen and platinum, both in contact with the electrolyte. It has been conclusively shown that platinum forms definite chemical compounds with oxygen and with hydrogen on coming in contact with these gases at ordinary temperatures. If carbon rods be substituted for the platinum plates, no galvanic action results, unless the gases have been produced electrolytically, in which case other chemical reagents are simultaneously generated in the solution at one of the electrodes and we have present at least three conductors. All other cases of galvanic circuits consisting of apparently only two conductors will be found to really contain at least three.

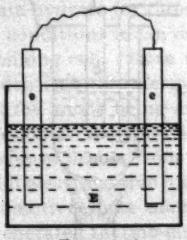


FIG. 12.

*Fig. 12* shows an interesting type of thermo-electric cell, which has been mistaken for a galvanic cell. It consists of two similar conductors, $e$ and $e'$, of the same substance, both in contact with the electrolyte, $E$. This it will be seen cannot at any temperature or under any circumstances constitute a galvanic cell, whatever may be the electrolyte or the substance composing the electrodes. But with certain electrodes and electrolytes it does constitute a most powerful thermo-electric apparatus. With a fused alkali hydrate as the electrolyte and iron electrodes the *E.M.F.* at temperatures between 500° and 700° C. may be as high as 1.2 volts. When the circuit is closed a current is compelled to pass through the electrolyte. This by Faraday's law necessarily

causes electrolysis, oxidizing iron at one electrode and reducing iron (from solution as oxide in the alkali) at the other electrode, the initial and final chemical states being identical, exactly as in the electrolytic refining of copper. *Fig. 13* shows another thermo-electric cell in which electrolysis is produced by the thermo-electric current, and in which the final chemical state contains more energy than the initial. In other words a thermo-electric current was produced which operated an electro-magnet in one part of the circuit and simultaneously stored up chemical energy within the cell itself. The apparatus consisted of a silver crucible, *S*, containing chemically pure sodium hydrate, maintained at a

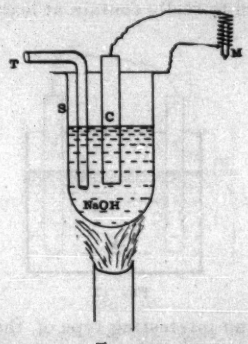



FIG. 13.

temperature of about 700° C. by a gas-flame and a carbon rod, *C*. The silver cup and carbon rod constituted the electrodes and were connected through the electro-magnet, *M*. A strong current of air was at the same time blown into the electrolyte through a silver tube, *T*. On closing the circuit a current of about .03 ampere caused oxidation of the carbon rod and reduction of metallic sodium at the walls of the crucible. The liberation of sodium rapidly increased and its combustion on reaching the air became so violent at the end of thirty minutes that the operation had to be discontinued. The crucible was found to be so thoroughly impreg-

nated with sodium at the bottom that it was spongy and useless and it crumbled with slight pressure, as you may observe by examining its remains. The electrolytic chemical change produced by the current is expressed in the following equation:

$$C + 3\,NaOH = Na_2CO_3 + Na + 3\,H.$$

The formation heat of $Na_2CO_3$ is 271,000 calories, while that of 3NaOH is 306,000. Hence, to produce the difference between the initial and final states, required the absorption of 35,000 calories from the heat applied, in addition to that required to produce the electrical energy expended in the rest of the circuit.

The Jacques "carbon consuming battery" differs from this only in the substitution of an iron pot for the silver cup and commercial sodium-hydrate for the chemically pure.

*Fig. 12* shows the conditions in an ordinary electro-plating or in a copper refining cell. Here the initial and final chemical states are identical, the energy evolved by the solution of the metal at the anode being exactly equal to that absorbed by its reduction at the cathode, the resistance of the cell and the transfer of matter from one electrode to the other requiring a small electromotive force from an external source. This electromotive force may, however, be very minute and may be generated thermo-electrically within the cell by raising the temperature of one electrode above that of the other. This may be done by making one electrode in the form of a tube, through which steam or hot water is conducted. Copper is deposited from a sulphate solution on the hot electrode and dissolved from the cold. In the sample here exhibited the deposit was formed in about twelve hours, the thermo-electromotive force being from ·04 to ·06 volt.

Another instructive illustration of thermo-electric action I hope to show you in the apparatus here exhibited. It consists, as shown in *Fig. 14*, of a zinc tray, *Z*, containing a strong solution of zinc chloride, to the bottom of which the heat of a gas-flame is applied. Into the heated solution of zinc chloride we immerse a clean strip of copper, *C*, without

allowing it to touch the tray. On withdrawing it we find that it is unchanged, there being no chemical reaction between the metallic copper and the zinc chloride. Immersing it again and bringing it in contact with the tray at any point, we find, on withdrawing it, that it is covered with a very smooth and perfect deposit of metallic zinc. This deposit is so perfect and intimate with the copper that on slightly heating it in the flame the two metals unite and form a very fine coating of brass. Iron and other metals not dissolved by the solution may be plated by the same process. The initial and final chemical states are here identical, and the action is thermo-electric. It is evident from *Fig. 14* that the metallic strip, *C*, is at a lower temperature than the tray, since it receives its heat only from the electrolyte, which in

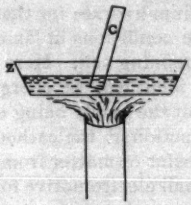



FIG. 14.

turn receives heat only from the tray. The junction of the electrolyte with the tray is, therefore, necessarily hotter than its junction with the copper strip. A galvanometer connected between the tray and the copper strip shows an E.M.F. of several tenths of a volt in the direction tending to deposit zinc on the copper, and on closing the circuit the deposition instantly takes place. This action is in nowise similar to the action of the copper-zinc galvanic battery, or to the deposition of metallic copper from solution on metallic zinc. In that case the same metals are present, but they are connected by a salt of copper instead of a salt of zinc. Metallic zinc acts chemically on all salts of copper by substitution, evolving in the reaction a large amount of chemical energy, which must escape either as heat or elec-

trical energy, and leave the final chemical state with less energy than the initial. But metallic copper cannot act by substitution on salts of zinc. Such a reaction would require the storing of the chemical energy which is evolved by the action of zinc on a copper salt. In our experiment the copper acts merely as a conductor, and is immediately covered up with zinc, but in the copper-zinc battery one metal goes out of solution and a more highly electro-positive metal takes its place. The copper zinc cell in its final and completely exhausted state is identical with this apparatus in its initial state and in every succeeding state. In it there is no possibility of evolving energy from chemical action, but by the continued application of heat it may be made to evolve electrical energy for an indefinite period. The mechanical destruction of the apparatus by the continued transfer of zinc from one electrode to the other may be theoretically prevented by applying the heat to the opposite electrode after a suitable interval of time.

By substituting a solution of zinc sulphate in *Fig. 14* for the zinc chloride we no longer obtain the deposit of zinc on the copper strip, showing apparently that the direction of the current is not the same for the two electrolytes.

Some additional experiments, however, suggested by Mr. Carl Hering and performed with his assistance, prove that the direction of the current is the same whether the chloride or sulphate of zinc is used, the direction being that which tends to deposit zinc on the copper, though the deposit can be obtained on a copper strip with zinc sulphate in a zinc tray only with difficulty. The reason is found in the great tendency of the zinc to redissolve and the copper to oxidize in contact with the sulphate solution. Nevertheless, the electromotive force, as shown by a voltmeter, is about ·6 volt, and is always in the direction tending to deposit zinc on the copper.

DISCUSSION.

A. E. KENNELLY:—As I understand this interesting paper, it deals with the question as to whether a cell containing a pair of elements and an electrolyte, and entirely

dependent for its electromotive force upon a supply of heat from an external source, is a voltaic or a thermo-electric combination. As pointed out in the paper, a voltaic cell is generally understood to deliver its electric energy at the expense of internal chemical energy; while a thermo-electric cell is generally understood to deliver its electric energy at the expense of externally supplied heat. Under ordinary conditions, therefore, it is usually easy to differentiate between the two types. Every voltaic cell at work is, however, always accompanied by thermo-electric action, and every thermo-electric cell containing an electrolyte is necessarily accompanied, when at work, by electrolytic action. Consequently, it may happen in particular cases, that the thermo-electric and voltaic actions in one and the same cell may be so blended as to make it difficult to determine on first inspection whether a cell belongs to the one type or to the other. Moreover, it is possible in a cell whose elements are similar in their electro-chemical condition at normal temperatures, that a dissimilarity may be produced by the application of heat in a dissymmetrical manner, so that one element, heated to a higher temperature than the other, might become endowed with chemical affinity for the electrolyte by virtue of the heat energy received. In every such possible case, however, there would necessarily remain this criterion as to the nature of the actions involved, viz.: that thermo-electric action is necessarily limited in its efficiency of transformation by the range of temperatures employed, according to the formula

$$\frac{T-t}{T};$$

whereas, voltaic action is theoretically capable of 100 per cent. efficiency. If, therefore, the losses of energy occurring in the cell can be measured, it becomes possible to ascertain whether the cell is a heat-engine or thermo-electric combination absorbing heat at one temperature and rejecting part of the heat at a lower temperature; or, whether it is a thermo-chemical engine or voltaic cell in which thermal energy is first commuted into chemical energy, and

this, in its turn, into electrical energy; or, whether it is both a thermo-electric and a thermo-chemical cell.

I do not think, therefore, that it can be demonstrated, in a general way, without experimental observation, that a cell depending upon heat for its energy is necessarily only a thermo-electric cell.

The coating of zinc upon the surface of the copper which is found in the interesting experiment we have witnessed, seems to possess remarkable properties, since it is said to be only with difficulty attacked by hydrochloric acid. It seems possible, however, that the coating of zinc being so thin, the zinc is in such close juxtaposition with the copper as to virtually partake of the nature of an alloy. If this were the case, the distinctive property should be lost as soon as the coating acquires an appreciable thickness.

PROF. JOSEPH W. RICHARDS:—I cannot accept Mr. Reed's conclusions in regard to the thermo-electric character of the Jacques carbon consuming battery, for the following reasons:

In the iron-soda cell, *Fig. 12*, p. 14, I fail to recognize any grounds for predicating thermo-electric action at all, for where are the unequally heated parts which are the essence of the generation of a thermo-electric current? With the Peltier effect, which concerns the conversion of electric energy into heat at a junction of two unlike conductors, we have nothing to do, when discussing the *generation* of the current itself. With the converse of the Peltier effect, Seebeck's discovery of the production of electromotive force at *two unequally* heated junctions, and Thompson's discovery of production of electromotive force in one unequally heated conductor, we are rightly concerned; but how can they be seriously considered in an apparatus *all parts of which are at the same temperature*. The occurrence of such phenomena in such an apparatus is excluded by the very definition of the phenomena themselves.

In the cell as there described, the electrolyte and electrodes are all at one temperature; therefore any thermo-electric effect produced by heating the junction of electrolyte and electrode on the one side, is neutralized by the

exactly opposite effect at the other side; and if we conceive the electrodes to be cooler out of the electrolyte than in it, yet any Thompson effect thus engendered in the body of one electrode would be neutralized by the exactly opposite effect at the other side. There are thus, as far as I can see, absolutely no grounds for predicating any thermo-electric effect, and, therefore, the cause of the current *must* be chemical action. I have conceived a possible chemical reaction in this case, but the data on which it rests are not quite certain enough to merit bringing the matter into this discussion. Perhaps a better explanation that I have in mind may be suggested by someone who, as I am, is convinced that a thermo-electric effect is absolutely out of question.

Coming nearer to the "Jacques cell," the reasons for assuming thermo-electric action in this case are very nearly as baseless as in the preceding cell. There is, theoretically, no unequal heating of any junctions or parts, and so it cannot in principle be a thermo-electric apparatus. On the other hand, there is present abundant material for supplying a chemical explanation of the action. Is it not well-known that pyrophoric iron will reduce caustic soda at redness? Was not Castner's original sodium process founded on the reduction of fused caustic soda by carbon weighted down by iron, and the temperature of a pot in which the reaction was in full operation was once measured at 823° C.? Did not Netto produce tons of sodium by trickling fused caustic soda over coke, in a retort heated to redness? There is thus abundant reason for assuming that at about 700° C., as given, the carbon simply acts reducingly on the caustic, separating out sodium electrolytically on the opposite electrode, the surplus energy of the reaction supplying the motive power of the current observed.

The reason why the thermal data do not correspond, is that those given by Mr. Reed are for combinations at 17° C. What the heats of formation of caustic soda and carbonate are at 700° we do not know, but it *is* known that carbon can reduce caustic soda at redness, and carbonate only at whiteness. Everything we do know points to the fact that the

heat of formation of the caustic soda decreases rapidly with the temperature, and more rapidly than that of the carbonate. If we only knew these exact heats of formation at 700° we could calculate the energy of the chemical reaction in this cell, and would then have the theoretical explanation of what we know as an observed fact.

C. J. REED:—The reason given by Dr. Kennelly for supposing that the action of the zinc-chloride and similar cells may not be thermo-electric, is that the efficiency of transformation of such an apparatus could not exceed $\frac{T-t}{T}$ if the process is thermo-electric. This is undoubtedly true and, for exactly the same reason, the process could not be thermo-chemical. The conversion of heat into chemical energy by absorption in an endothermic reaction, or into any higher form by any process whatever, comes under the same limitations. If there is any voltaic transformation of the chemical energy so stored or formed, it must necessarily be subsequent to the thermo-chemical or storing process, and the total efficiency of the two processes would be still less than that of either the thermo-chemical or the thermo-electric alone. Inasmuch as there is no record of any measurements having ever been made, that show an efficiency even remotely approaching the theoretical limit, it seems to be unnecessary to set up a new theory to account for something that is not known to exist and is not likely to be established.

The only experiments yet published, in which efficiency is claimed to have been determined, are those of Dr. Jacques, who claimed an efficiency of about 32 per cent. But Dr. Jacques made no measurements of the temperature at which the heat was either received or rejected in the process. In fact, he claimed that there was no difference in temperature between the different parts of his apparatus—a claim that is manifestly absurd. From what is known of his experiments it is quite certain that the heat was received in his experiments at about 800° C. (absolute scale) and the temperature at which the heat was probably rejected did not exceed 300° C. The maximum efficiency of thermo-electric transformation would, therefore, have been about

$\frac{800-300}{800} = 62$ per cent., which leaves a considerable margin of possibility after allowing Dr. Jacques all he claims.

The difference T–t, which must be used in this calculation, is not, as has been popularly supposed, the difference of temperature between the hot electrolyte and the hot end of the inserted electrode, but the difference between the hottest and the coldest parts of the electric circuit, these being the points at which the heat is received and rejected if the action is thermo-electric.

Admitting, however, for the purpose of discussion that some other explanation is necessary than that of thermo-electric action, the theory of Mr. Steinmetz, which Dr. Kennelly seems to support, presents difficulties which are very great. It assumes that in a given system, comprising an electrolyte and terminal conductors, the energy of the system itself remains unchanged, while the system continuously absorbs heat at one point, converting it into static potential energy, and at another point this energy or its exact equivalent passes out of the system in a dynamic condition by a process which is necessarily both subsequent to and simultaneous with the process of storing (absorption). Inasmuch as the energy of the system, as a whole, remains constant, this process of subsequent and simultaneous change from a static to a dynamic condition, supposed to take place within the system, must necessarily be a theoretically perfect process having an efficiency of 100 per cent. Such a process seems to involve a contradiction of terms in its definition. Furthermore, this subsequent and simultaneous process explains nothing, except what is easily explained by thermo-electric action, according to which the heat would be absorbed directly by the circuit and simultaneously evolved as electrical energy without any intermediate process. Another objection is that if any such process exists, its very nature precludes the possibility of its being experimentally detected. Its existence could not even be proved by the indirect method of efficiency test suggested by Dr. Kennelly, since the efficiency of such a process could not exceed that of a heat engine.

The deposit of zinc on the copper, obtained in the experiment with zinc chloride, possesses certain peculiarities, from which I at first thought it might not be zinc, but an unknown *constituent* of zinc. The explanation offered by Dr. Kennelly that it is an alloy of zinc with the copper plate seems much more plausible, though an alloy of copper and zinc having the color of zinc and the chemical inactivity of copper is somewhat remarkable. The deposit is acted on only very slowly by acids, even when in contact with platinum foil.

Dr. Richards seems not to have understood that *Fig. 12* is merely *diagrammatic of the parts of the apparatus only* and is not intended to represent the apparatus in action nor its form. A thermo-electric apparatus, like a dynamo or galvanic battery, may properly be called such, whether it is in action or not. A dynamo standing idle may really be nothing but a mass of copper and iron, yet it is usual to call it a dynamo. It is to be understood, of course, that a thermo-electric apparatus in action requires the application of heat in such a manner as to produce unequal temperatures in different parts of the circuit.

The relevancy of Dr. Richards' remarks concerning the chemical reactions of the Jacques cell is not clear. The fact that carbon reduces sodium and most, if not all, metallic oxides at sufficiently high temperatures is generally accepted. It is well known, however, that such reactions do not evolve energy, except in the case of easily reducible metals, whose combustion heat is less than that of the carbon equivalent of the oxygen transferred. What does Dr. Richards mean by "*the surplus energy of the reaction supplying the motive power?*" What is this surplus energy and where does it come from? What chemical reaction takes place evolving any energy? The fact that metallic oxides having high formation heats are reducible by carbon only at correspondingly high temperatures is due to the fact that only at those temperatures can sufficient heat be absorbed to overcome the chemical affinity of the constituents of the compound and restore to them their original chemical energy. There is no surplus energy present, except the surplus heat of the furnace.

The formation heat of NaOH, like that of all other substances, is merely the heat given out or absorbed in bringing the substance formed in a reaction back to the initial temperature of the reagents. For the temperature of dissociation the formation heat of any compound is zero, and for any lower temperature it is the difference between the low temperature and the temperature of dissociation in degrees multiplied by the mean specific heat of the compound between those temperatures. The formation heat of any substance at a high temperature is always less than at a low temperature by the amount of external heat absorbed in passing from the low to the high temperature, and the determination of the formation heat at a high temperature would merely amount to the determination of the mean specific heat between the high and the low temperatures. Any electrical energy that could in any way be due to a diminution of the formation heat of NaOH at an elevated temperature would, therefore, be due solely to the external heat absorbed in raising and maintaining the temperature. The proper temperature at which the formation heat should be taken is the final temperature at which the heat is rejected when the body cools. In this case it is necessarily the temperature to which the electrolyte cools down after the source of external heat has been removed. In other words, the only energy that can originate in the system is that which it contains before any external heat is applied.

*Stated Meeting, November 8, 1898.*

## THE STATUS OF ELECTRICAL INVENTION.

By William A. Rosenbaum.

The old saying that "There is nothing new under the sun," once found a firm believer in no less a personage than a member of the examining corps of the United States Patent Office. The gentleman referred to resigned his position for the reason, as given by himself, that he believed invention was about at an end, that in the then existing per-

fect state of mechanism and appliances nothing more was to be desired or attained and that the Patent Office would soon have to close its doors, whereupon he would be left without employment.

It is needless for me to say that this did not occur recently, for the march of progress is so rapid nowadays that the tendency is to predict more and greater discoveries rather than that mechanical and scientific progress has reached its limit. As a matter of fact, this prophecy was made before the invention of the sewing machine, the cotton gin, the type-writer, the perfecting printing press, and when the status of commercial electric invention was determined by the Voltaic battery and the simple telegraph. Curiously enough, the incident really marked the very threshold of the epoch in which all of our great electrical inventions were produced.

Since the beginning of this epoch, so rapid and effective has been the progress of electrical invention, that each branch of the science, from the moment of its inception, has been developed to a state closely approaching perfection, within a few years. In saying this, I do not mean to step into the shoes of the Patent Official and imply that there is no further room for improvement in the fields that have been entered, but rather that each branch of the science has had its pioneer inventions, followed quickly by the usual multitude of "improvements," interspersed here and there by controlling inventions, or "milestones," directing the lines of thought, and all subjected to the fining processes of the designer and engineer until, within a few years, sometimes less than a decade, the subjects have been given their definite character.

Notwithstanding the fact that the United States Patent Office is now issuing about twenty-five patents per week relating to electricity, it is noticeable that there are but few controlling inventions among them. Indeed, in the fields of telegraphy, telephony, electric lighting, electric railroading, chemical and mechanical generation and the storage of electrical energy, it is difficult to point to more than two or three controlling inventions of so recent origin as to be

within the last five years. And when we parallel this with the statistics showing the stupendous extent to which it has been possible for these subjects to interest capital, if we were not progressive, we might be prompted to believe that these branches of the science at least, have been perfected. The production of the commercial underground trolley furnishes an apt illustration of how invention in any art may come to a standstill, and even have its "rise and fall." Following the proposition to put the overhead trolley underground, came an avalanche of invention showing how not to do it.

Systems without number came out involving sections, sub-sections, relays, cut-outs, switches, sparkless contacts, methods of insulation, and so forth, the general object being to avoid leakage and render the line safe to persons and animals. But the futility of all this effort was suddenly demonstrated by the operation of one or two sub-trolley roads whose electrical construction was practically the same as that of the overhead system, to-wit: a bare live conductor supported upon insulators. In consequence, the avalanche of invention soon flattened out and gave way to the earliest and simplest ideas.

Naturally, the arts have been developed more rapidly in modern times than formerly. While the telegraph which originated in 1840, required about forty years, the telephone, which originated in 1876, only required about fifteen years in its development, and while it may be urged that telephony has not reached the same state of development as telegraphy, yet I think it lacks only a serviceable repeater to have acquired the same distinction.

Likewise, the dynamo-electric machine, which resulted from Faraday's experiment of 1831, and its converse the electric-motor, were of but little real value until half a century later, when the progress made in the theoretical treatment of magnetic problems made it possible to predict the electrical and mechanical output under given conditions of speed and load. Contrary to this, the two branches of the science, electric lighting and electric railroading, the two industries made possible by the dynamo and electric motor,

were developed, the former to a standstill, within fifteen years, and the latter within a decade.

In approaching more closely the subject of this paper, the writer may be permitted to say that some difficulty was experienced in determining on what plan the paper should be constructed in order that it might contain information of value. The subject refers to "invention" and not to engineering or commercial progress; it was, therefore, finally decided to take up the main branches of the art successively, and refer to those inventions in each which have been responsible for, or have directed the lines of, its development. It is believed that no systematic attempt in this direction has been made heretofore, and that a recitation of the inventions that have given shape to the art, with brief descriptions of each, may possibly prove to be of some interest and value.

Since the telegraph has the precedence in point of time among electrical devices affording commercially successful results, we naturally turn to it first. Up to twenty-five years ago the simple Morse system of telegraphy was the only one in general use. Experiments had been made with printing and chemical automatic systems, and although the duplex system was in limited use, it had not been perfected. As to the beginning of the art, the needle telegraph of England, I believe, has the precedence, but this was very shortly followed in 1840 by the more practical system of Henry and Morse, the electro-magnet of which is the responding element of the American telegraph system to the present day.

The key is one of the most important instruments of the system. A vast number of patents have been taken on it, the object of invention having been primarily to transform the old, heavy, cumbersome mass of brass introduced by Morse into the light "solid lever" keys used in this country at the present time, and of which the "Bunnell" key is the pioneer.

The relay, another important instrument, has undergone many changes in shape, dimensions and resistance since it was first invented. In weight alone, it has changed from about 300 pounds to 3 pounds. But improvements of both

this instrument and the sounder have been more the work of the designer than that of the inventor. The Morse register, which was formerly in use as the receiver, has been superseded by the present method of receiving by sound.

The first repeaters were known as the "button" repeaters; they were not automatic, since they required an operator in the repeating office to prevent interference. These were superseded by the automatic repeaters of Milliken, Horton, Weiny and a few others, in use to-day.

The "duplex" appeared first on paper, in 1858, and was not followed by anything more substantial till early in the seventies, when the well-known Stearns system appeared, which, with slight improvements, has remained the standard to the present time.

In the "quadruplex," since the work done by Mr. Edison in 1878, there have been few changes of consequence to record. With the substitution, however, of dynamo machines for batteries, to obtain quick acting increase and decrease of current on the quadruplex circuits for the operation of the distant relays, without affecting the resistance of the main line, the dynamo quadruplex key system was devised and is in use to-day by the Western Union Telegraph Company. In multiplex telegraphy the Delaney synchronous multiplex takes a prominent place, and is in use at the present time.

The need for rapid transmission brought out the automatic systems, in nearly all of which the message is first either punched, embossed, painted or chemically printed upon a strip of paper which is afterward fed into the transmitter. The chemical automatic systems have nearly all been superseded.

The writing telegraph is now being developed into commercial state. Its principle of operation is that of "compounding the movements of a point in two directions, the one at an angle to the other, the actual movement of the point being the resultant of the two movements."

Telegraphing from moving trains has been given some attention, the most successful system from a commercial standpoint being that which depends upon the laws of electromagnetic or electro-static induction.

The printing telegraph is largely in use for stock quotations and news. In general, such systems depend, primarily, for success upon the uniformity of rotation of a cylinder or wheel at a transmitting station, with a type wheel at a receiving station.

Long submarine telegraphy has not advanced with its increasing traffic, the difficulties in the way of high speeds having been only partially overcome. The Morse receiving apparatus, which was first tried with a speed of one or two words per minute, has been superseded by the Thompson, and later, on some lines, by the Cuttriss syphon recorders.

Much of the later work of telegraph engineers has been in the improvement of apparatus and the development of means for increasing the capacity of existing wires by the use of automatic and multiplex systems. The most recent and important result of this work is the synchronograph of Crehore and Squire, which bids fair to adequately meet any and all demands in the direction of rapid transmission for many years to come. A description of this system, even in brief, cannot be attempted here; suffice it to say that it has been practically used, and is capable of transmitting and receiving from 3,000 to 4,000 words per minute.

While formerly the telegraph was devoted to business and social use, it has now become an indispensable agent in the operation of fire, police, burglar and many other analogous systems, a detailed reference to which the limits of this paper will not permit.

Telegraphy through the medium of wires may, perhaps, be said to be fully developed. The best evidence of this is the fact that the field of "wireless" telegraphy has been entered and advances made well into the experimental stage. Telegraphing without wires over distances less than ten miles is an accomplished fact. The principle upon which this system is based may be described as follows:

At the transmitting station mechanism is provided for sending into space, whenever the signalling key is closed, regularly occurring electrical waves at a predetermined rate. These waves traverse the space intervening between the transmitter and receiver, are collected by the receiver

and sent through a metallic powder, the particles of which are in loose contact and normally offer such high resistance as to obstruct the flow of a battery current directed through it. The passage of the waves through the metallic powder causes its particles to cohere, and reduce the resistance sufficiently to permit the battery current to flow and operate a relay. Automatic devices are employed to loosen the powder particles the moment the sending key is opened.

The great inventions in telephony were made within the five or six years following the time when Alexander Graham Bell proved telephony to be a practical thing. The Centennial Exposition of 1876 was fortunate in at least two things —first, that it was held in Philadelphia; and second, that it made the first public exhibition in the United States of the articulating telephone.

The principle underlying the operation of the telephone, since its inception and to the present day, is best stated in that famous fifth claim of the fundamental Bell patent of 1876, to wit:

"The method of . . . transmitting vocal or other sounds telegraphically, . . . by causing electrical undulations, similar in form to the vibrations of the air accompanying the said vocal or other sounds. . ."

The multitude of devices that have been invented for transforming these air vibrations into "electrical undulations" may be divided into two classes: those in which a magnetic field of force is varied, and those in which the nature of mechanical contact between a plurality of conducting bodies, is varied.

The introduction of the telephone to commercial uses necessitated the supply of various auxiliary devices for calling and interconnection purposes, and the several thousand patents issued in the art attest to the vast amount of invention that has been necessary to bring it to its present degree of perfection. Brief reference to the most important of these will follow.

First of all came the Bell instrument used both as transmitter and receiver, and as in use to-day as a receiver only, is practically of the same construction as the original instru

ment, consisting merely of a magnet facing up a flexible disk forming or carrying the armature.

Following this very shortly, came the microphone or carbon transmitter, in which the movements of a diaphragm varied the pressure upon a body of carbon forming a part of the circuit. This instrument had many modifications involving carbon buttons, carbon pencils, balls and carbon powder, but no substantial changes have been made in late years.

The induction coil was the next important piece of apparatus. This made its appearance in 1877 and by virtue of it, it became possible to telephone to considerable distances with an initial current of low electromotive force. This device still plays its important part in all extended systems. The induction coil and the microphone transmitter brought into use the Voltaic battery in connection with telephony.

Various forms of calls have been invented and used, but the most acceptable and one of the earliest, is the magneto call by which the user generates the calling current. Allied to this is the automatic switch (1879), the function of which is to cut the calling magnets into circuit when the receiver is hung upon its supporting hook and to remove it from the circuit when the receiver is put into use.

We next come to the switch-board, an apparatus which has built up from the simplest beginnings to an extremely complex mechanism, in parallelism with the phenomenal growth of the telephone business.

The simplest instance of communication is a line with a single apparatus at each end. Following this came three or more instruments in series on one circuit with the consequent liability of interference, and a modification of this consisted in putting the instrument in parallel and using bridging bells. Then came the multiple circuit system with its multiplicity of wires and the objection of permitting conversations to be overheard. In all of these systems the person calling made his own connections. Next came central-station switch-boards. The simplest form is the single circuit board to which the wires from each instrument lead, and are there connected by an operator, as required. The

metallic circuit or "double wire" was the obvious modification of this. In small exchanges either the single or double circuit simple board presided over by one or two operators, is in use to-day, but for large cities where the exchanges accommodate a thousand or more subscribers, the single board was found to be inadequate and the invention of the multiple switch-board followed. As its name indicates, it is a plurality of single boards or sections, to and through each of which, every subscriber's line extends, with means on each section for establishing connection with the line of any other subscriber. Multiple boards are either single or double circuit.

In long distance telephony, the problems have been more for the engineer than the inventor. The apparatus differs only in details from that in use for short distances.

In the production of an efficient repeater, inventors have spent considerable effort without marked success. So soon as we shall have a satisfactory automatic repeater, telephony will have reached practically the same state of development as its sister art, telegraphy.

The fundamental inventions in electric lighting were practically all made prior to 1884, and what there is of interest subsequent to that time, to record, is mainly the work of the electrical engineer or skilled electro-mechanic. It is not expedient herein to give a history of electric lighting from its very beginnings; suffice it to say that during the seventy-five years following the discovery of the Voltaic arc, a number of hand and automatically regulating arc lamps were produced, and for the same period following the discovery that a continuous conductor could be brought to incandescence by passing a current through it, a variety of incandescent lamps were invented, even to involving the burning of carbon wires in an exhausted glass vessel. But the failure of any lamp in either class of lighting, to become a commercial success, was due as much to the lack of a sufficiently cheap source of current as to the inherent defects of the lamps themselves.

[*To be concluded.*]

# CHEMICAL SECTION.

*Stated Meeting, September 20, 1898.*

## HIGH EXPLOSIVES AND SMOKELESS POWDERS AND THEIR APPLICATIONS IN WARFARE.

BY HUDSON MAXIM.

[*Concluded from p. 386.*]

By the sacrifice of a little velocity, but still leaving us a velocity of 2,000 feet per second, we may make our aerial torpedo to weigh 1½ tons, and to consist of 1 ton of steel, carrying a bursting charge of ½ ton of high explosive. This projectile would be sufficiently strong to enable it to penetrate the deck armor of any battleship in the world before exploding, or to penetrate the belt armor of protected cruisers like the "New York" and explode inside the vessel. That such an explosion would be destructive in its effects I think all will be willing to grant.

The fuse to be employed is one of the chief features of the aerial torpedo. The question of fuse has always been one of the principal features of the problem of successfully throwing high explosives from ordnance. Briefly, it is constructed in such a way as to absolutely preclude any danger of premature explosion in the gun, and when the projectile strikes the target, the action of the fuse is sufficiently delayed to permit the penetration of the projectile to a desired depth in earth or water, or to pass through light armor before exploding.

Let us now see what may be done with but a very slight change in present forms of ordnance and in present forms of shell. Let us take a gun of the same weight and cost as the present 12-inch, 52-ton, sea-coast rifle, and let us construct it to throw a projectile weighing 1,500 pounds, 1,000 pounds of steel and 500 pounds of high explosive. The caliber of the gun would be about 20 inches. The projectile thrown

would have a velocity considerably greater than the present 1,000 pound 12-inch shell, carrying a bursting charge of only 37 pounds of black powder.

Now, when we take into consideration the fact that it will not cost any more for a gun to throw aerial torpedoes, carrying bursting charges a hundred times as powerful as are now thrown, and without any sacrifice in velocity, but that we may even attain greater velocity, flatness of trajectory, and directness of fire than are now attained with high-power guns, and still throw enormous charges of high explosives, the value of this system ought to be apparent.

The system involves no radical departure from present forms of ordnance. The aerial torpedo involves nothing questionable or intricate in its construction, and no new or untried law, and, as has already been stated, there are several high explosives which may be thrown with perfect safety.

Lyddite, which is simply picric acid, is already employed by the British Government for filling shells for high-power guns, and this same material, either alone or admixed with other ingredients, has been long used by some of the Continental European powers.

In the *Westminster Gazette* of August 26th last, it is said that, "The reports to hand from the Soudan Expedition indicate that in the attack upon Omdurman great reliance will be placed upon the mischief-making power of the new lyddite shell. It is stated that when tried at Abu Sieh, Cairo, the effect of the time bursts were simply terrific, and it is asserted that the concussion of a burst can have effect 600 yards to the front and 300 yards to the rear."

What I propose is simply to throw larger quantities, but without subjecting the explosive to any greater shock in the gun than that to which it has been already subjected and been found to successfully withstand.

This should be borne in mind, that the same explosive that is now widely used for filling shells for high-power guns, may be used to fill aerial torpedoes, and that, in the aerial torpedoes, it will not be subjected to any more shock than that to which it is now subjected.

As already stated, it is the length of column of the explosive in the projectile that must be taken into account in considering the shock of acceleration upon it In the aerial torpedo proposed by me, the column of explosive would be subdivided by a strong cross partition, and no matter how large the shell may be in cross-section, the shock is no greater than as though it were but a few inches.

Naval and military authorities must soon give due consideration to the aerial torpedo. From ½ a ton to 1 ton of high explosives can certainly be thrown with absolute safety and great accuracy at all fighting ranges at sea, and if such quantities of high explosive, striking and exploding on board a battleship by impact upon its superstructure, will destroy the vessel or throw it out of action, or if such quantities, when projected into the water, and exploding as submarine mines adjacent to the hull of a battleship, will suffice to blow her up or sink her, then the first shot of the aerial torpedo gun proposed by me will render obsolete every battleship in the world.

Immense sums of money will no longer be expended in armored protection which will not protect, and in the construction of huge and ponderous fighting machines whose very size renders them a more easy prey to the torpedo gun than a small and light cruiser, simply big enough to provide a portable and stable gun platform. If a projectile can be thrown which shall be sufficiently destructive to demolish anything and everything it hits, then, obviously, thereafter centralization of men and expense must be abandoned and men and weapons must be dispersed in order to form as many and as small targets as possible. Navies must fight in skirmishing order, exactly as armies on land now do.

If the battleship, forming a target ten times as great, offers no greater protection against the aerial torpedo than the small, unprotected cruiser, and costs ten times as much and carries ten times the number of men, it is certainly not more than one-tenth as efficient a fighting machine. Anything revolutionary in character, however meritorious, always has a hard fight for recognition, especially in overcoming the opposition backed by enormous vested interests.

It would be easier with a few cruisers armed with aerial torpedoes to make a scrap heap of every battleship of the combined navies of the world to-day, than it will be to even secure the system a place for once in the line of battle.

If there is even a fighting chance for the aerial torpedo to work the revolution in naval construction predicted, then this matter is a subject for serious consideration, especially by the United States Government, before making the enormous expenditures in battleships which Great Britain has made. Half a million dollars will build and arm a light torpedo cruiser which will carry one 24-inch torpedo gun and two torpedo mortars. This will demonstrate the efficiency of the system. If it fails, it costs but $500,000; if it succeeds, it will save $500,000,000. The battleship must go.

The great distance to which enormous quantities of high explosives may be thrown by torpedo guns and mortars and the hitting qualities of these weapons, when the enormous size of the target is taken into consideration within whose area a torpedo, striking, will destroy a warship, renders these weapons of supreme importance for coast defense.

Aerial torpedo guns, when once successfully tried, either on land or sea, will cause a revolution in coast fortifications as well as in war vessels. Aerial torpedoes penetrating deep into earthworks before exploding will be disastrous. It will then be the weapon rather than means of protection, that will be the dominating factor in both attack and defense. The cost by present methods, in ammunition and wear and tear of guns in bombarding coast fortifications or towns, is quite equal to the amount of damage done. This will all be changed by the introduction of aerial torpedoes.

The American fleet expended more than $2,000,000 worth of ammunition hurling shot and shell at the Santiago hills, and the damage wrought was quite insignificant, probably not more than 10 per cent. of what it cost the American Government in ammunition alone.

The "Vesuvius" threw a few shells carrying only 200 pounds of guncotton, and without any power whatever of penetration. Not much could be expected of these.

Suppose a few aerial torpedoes weighing a ton and a half, with a bursting charge of half a ton, and capable of penetrating deep into the fortifications before exploding, had been employed, would not the result have been vastly different? Would not enormously greater destruction have been wrought?

The lessons of the present war do not, as claimed by certain persons, teach us the uselessness of torpedo boats and of torpedo warfare, and nothing has been learned upon which to found any higher opinion of the battleship than we had before the war. The great lesson taught is the superiority of the American gunners and Americans as fighters.

Suppose, for example, that Cervera had had such a number of torpedo boat destroyers, of the Pluton and Furor type, as could have been constructed for what the American battleship "Oregon" cost—say twenty of them—and suppose those torpedo boats had been armed and equipped with American guns and ammunition, American torpedoes, and manned by Americans, and that they had sallied forth at night instead of in the daytime, and made a determined attack upon our fleet, is it not probable that they would have succeeded in destroying more of our war vessels than they themselves cost before they could have been destroyed?

Furthermore, suppose there had been mounted upon the Santiago hills, torpedo guns capable of throwing ½ ton of high explosive over a radius of from 8 to 9 miles, might not the result have been different?

In these ante-millennium times, war is occasionally a necessary contingency, and when it comes we want the best tools we can get to fight with, and it is a crime for a nation not to be prepared for war, a crime against those who will be called upon to defend the country in time of war. It is a crime for a nation not to be abreast of the times in arms and equipments.

Improved guns and ammunition, improved methods for the employment of the most destructive agencies of offense and defense are but means of saving life. Modern armies and navies are but elaborate and efficient life-saving sys-

tems, and are as humanitarian in nature as the life-saving services along the coast of civilized countries, whose duty it is to warn vessels of danger and to succor those who may be cast away. The fort is as humanitarian in its nature as the lighthouse, and the seacoast gun as much an implement of mercy as the gun that throws the life-line to a stranded wreck.

The cost to this country of the present war with Spain, above what it would have been had the country been prepared for war, is difficult even of approximation—prepared in every sense, as well as with armaments.

It is doubtful if there would have been any war had not Spain been encouraged by her belief in our weakness or unpreparedness, for it was not only generally believed in Spain, but by many in other European countries, that Spain would at first have the best of the fight. The world has been taught a lesson by a reminder of the fighting qualities of the American character. We have also been taught a lesson which the country ought not soon to forget—the necessity of being prepared for war.

The country which finds itself involved in war in a state of unpreparedness, can make good deficiencies in such respects only at the cost of great sacrifice of life.

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War must be looked upon as a business, and subject, like any other business, to business principles. War is the business of destruction of life and property of an enemy, and has no regard for the sacredness or pricelessness of human life. Lives become part of the paraphernalia of war, and lives and property become representative in value. The art of war consists in the employment of means and instruments to accomplish the desired purpose with the minimum of risk, expenditure and loss on the investment.

The history of nations is the history of wars. The millennium of secure universal peace is yet far off. There will be need of guns just so long as one man, through eyes of injustice, sees any use for another man's property, or until all nations shall unite in a common federation, a universal

family of mankind, bound to peace under laws made in the common interest, when shall be realized that ideal society mentioned by Tennyson:

"The parliament of man, the federation of the world."

At best, war is cruelty, but it is not only often a necessity, but unavoidable, and once engaged in should be made as terrible and destructive as possible while it lasts, in order that it may be brief as possible, thus minimizing the evil in the aggregate.

Not only do swords and bayonets, guns and gunpowder, torpedoes and high explosives constitute the weapons of war to-day, but the steamboat, railroad, telegraph, the woollen and the cotton mill stand on the plane with the rest; the chemist, electrician, engineer and inventor, find duty as serviceable to their country as does the bleeding soldier; and all the vast industries of a great commonwealth unite with its husbandry to supply the sinews of war. By just division of labor, the ploughman, artisan, scientist and inventor strike as nobly for their country and render her equal service as though they were to fight and bleed and die upon the field of battle.

One man, with a Maxim-gun, is worth more in a fight to-day than would be 100 men armed with the old-fashioned muzzle-loading rifles used as late as the American Civil War. The new magazine rifle makes a single soldier more than a match for a dozen men armed with the old weapons.

A troop of artillerists operating modern quick-firing guns, with shrapnel and canister, could stand against ten times their number armed with the old smooth-bore muzzle-loading field guns. What does this mean? It means that only one-tenth as many men need be sent away to war, while the remaining nine-tenths may stay at home.

It may be argued that an enemy would be equally well equipped. Very true. But his equipments and the home industries producing them demand of him also that the nine men work and only the tenth man fights.

There can be but one interpretation as to the results upon civilization of improvements in implements of war,

and it is that more will be done by money and machinery and less fighting done by hand, permitting and demanding that large numbers remain at home engaged in industrial pursuits, while the home is defended less by blood and more by the fruits of industry.

The most deadly and destructive implements of war are the most humane, and the producers of them may justly be looked upon as humanitarians. The best guaranty of peace is to be in a position to make a breach of it as undesirable as possible to an enemy. The greatest security against receiving heavy blows is to be in a position to strike them. Peace is made most secure by being prepared for war, by pushing to the highest state of development possible the weapons and means of offence.

The inventors of deadly engines of war place in the hands of scientific and enlightened nations the means of controlling wars. Such inventions have put a limit to the time when barbarian hordes can overrun and subdue the earth, to ravage, destroy and enslave by sheer brute force and power of numbers.

## CHIMNEYS FOR INCANDESCENT GAS LAMPS.

By Ernest M. White.

In the year 1880 or thereabouts, Carl Auer, a student of chemistry at Heidelberg became interested in the subject of gas lighting. Believing in the incandescent principle, he directed his experiments, research and study, along the lines of that system; producing, eventually, the Auer or Welsbach incandescent gas lamp, which has recently revolutionized the Science of Gas Lighting.

Following closely, some years ago, the evolution of the incandescent gas lamps and the improvements made in it by Auer and other inventors through whose hands it had passed, I found that no real improvements had been made in the chimney. This is by no means an unimportant ele

ment of the lamp, its function being partly to protect the mantle from injury, and partly to create draft sufficient to supply to the mantle the oxygen necessary for the combustion of the gas.

Recognizing the defects in the Argand chimney used on the incandescent gas lamps and believing it possible to overcome them and to use the mantles after they had become broken or torn, I began a series of experiments with the narrow cylindrical chimney in general use and all the other forms that came to my notice, some of which I shall show and explain, together with one invented by myself,

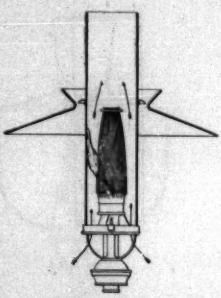

FIG. 1.

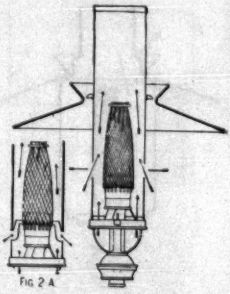


FIG. 2.

which is constructed upon a new principle in incandescent gas lamp chimneys.

*Fig. 1* shows the single draft narrow cylindrical, or Argand type of chimney, the best known perhaps of all those used on the incandescent gas lamps. These are made of glass or mica, and, in order to obtain sufficient draft are made of small diameter, about 2 inches. Owing to the close proximity of these to the mantle, as soon as that delicate fabric has become torn, they are almost invariably cracked by the flames inpinging upon the inner walls and in breaking they usually carry with them the mantle. At times, however, such glass chimneys do not break until hours after the light has been turned out. I know of one case in which breakage

occurred some weeks after the chimney had been taken off the lamp.

*Fig. 2* is a narrow chimney known as the "Tweer," in which I have placed near the bottom a number of small holes. The air entering these openings, mixes with the ascending column of air, bringing oxygen constantly in contact with the mantle, rendering combustion more nearly perfect, and the mantle incandescent to the very top, producing a more brilliant light.

*Fig. 2 A* is a blower placed beneath the narrow glass chimney and intended to improve combustion.

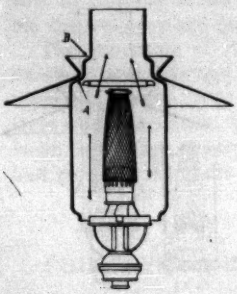


FIG. 3.

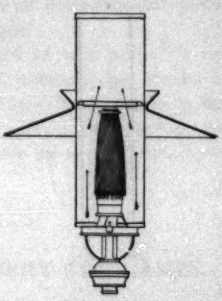

FIG. 4.

*Fig. 3* shows an attempt to overcome the breakage of the chimneys and to use broken or torn mantles. It has all the faults of the narrow chimney, and, owing to the sluggish single draft through it, the combustion is imperfect and the light obtained about 25 per cent. less than that obtained with the narrow chimney. Furthermore, the conformation of the top of this device is such, that, by the unequal expansion it is frequently broken at the shoulders *A* and *B*, the moment the flames come in contact with it. When this occurs, the shade which is supported by it usually falls with it and is also destroyed.

*Fig. 4* represents a wide single-draft chimney about 2⅝ inches in diameter and made of mica, designed evidently to

correct the faults of the foregoing globe and the narrow chimney. The light with this chimney is remarkable sensitive to air currents and is very inferior to that produced with the narrow chimney.

*Fig. 5* shows a combination of a large globe and a metal top, which serves as a shade. This had its origin in the mind of Mr. Arthur Paget, an English inventor. It is undoubtedly, in many respects, superior to the foregoing devices. Like these, however, except when the gas pressure is very high, the light it affords is much below that produced with the narrow chimney, and in appearance it is not at all pleasing to the eye.

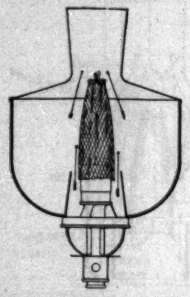

FIG. 5.

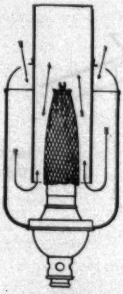

FIG. 6.

FIG. 7.

*Fig. 6*, Mr. Daniel Macfie, another English inventor, has devised this form of chimney. Practically, this is the narrow chimney surrounded by a large globe closed at the bottom. The principal function of this enclosure seems to be to render the light more insensible to air currents, and to prevent the chimney flying about when it breaks.

*Fig. 7*, like the foregoing devices, had its origin in England, and is a two-part chimney. One part is above and the other surrounds the lower part of the mantle. Some few improvements in the details of this device are found in U. S. Patents granted to Marsh. It is used somewhat in lamps for street lighting. In candle-power the light does not equal the Argand chimney.

*Fig. 8* is a modification of that shown by *Fig. 7*, and forms part of patents granted to E. M. White. This is not a forced draft chimney, but a ventilated globe. The light produced with this device while not equal to that of the narrow chimney, is better than that obtained with any of the previously shown devices intended to use damaged mantles. The breakage of the glass is rather high.

*Fig. 9* represents the outline of a chimney devised by myself and which is constructed upon the ejector, or automatically forced-draft system. This involves a new principle in incandescent gas lamp chimneys, and is intended to

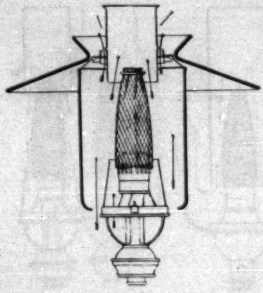

FIG. 8.

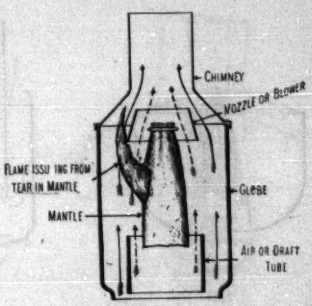


FIG. 9.

use damaged mantles, to overcome the destruction of chimneys and to render the light less sensitive to air currents.

This device, which dispenses entirely with the very troublesome narrow chimney, consists, essentially of a globe about 3½ inches in diameter, which forms a combustion chamber, an air-tube surrounding the lower part of the mantle to separate and to direct the drafts, and an ejector or jet blower which is made of metal and placed immediately above the mantle.

In this chimney, the rapidly ascending column of the products of combustion (called the central draft and indicated by dotted arrows) enters the blower or ejector nozzle, where it acts the same as steam in an ejector, inducing an

outer draft, which, moving upwards close to the inner walls of the globe, forces away from the glass and into the metal chimney the flames issuing from holes or rents in the mantle, thus reducing the breakage of the glass to the lowest limit, and uniting with the central draft above the blower, emerges through a chimney common to both.

It has been demonstrated with this chimney that the light obtained is equal to that produced with the Argand type, is clearer and diffuses better, and with broken and torn mantles is frequently brighter than it is possible to obtain with mantles in perfect condition. It has also been found

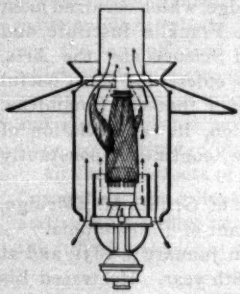

FIG. 10.

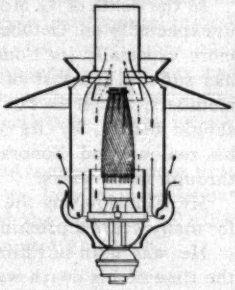

FIG. 11.

with it that mantles that are broken, torn and apparently worthless can be used as long as there is a shred left, and that their useful life is increased from three to five times. The breakage of glass is reduced to the lowest possible limit, and, furthermore, the globes do not need the frequent cleaning necessary in the case of the narrow type.

*Fig. 10* shows the way the chimneys are applied to the Welsbach light and how the flames are forced away from the glass.

*Fig. 11* illustrates this chimney, with a draft guard, intended for use in halls, corridors, etc.

This system of chimney seems to be the most economical, efficient and practical chimney yet produced for the

incandescent gas lamp. With its aid the users of this most excellent light are enabled to realize all of the saving in gas that it is possible to effect by the use of the incandescent system, without being obliged to spend this saving and often more for new mantles and chimneys.

## IN MEMORIAM.

### G. MORGAN ELDRIDGE.

In the death of G. Morgan Eldridge, which occurred most unexpectedly on October 20th, the Franklin Institute, and more especially its Committee on Science and the Arts, has suffered the loss of one of its oldest and most useful members, and it is eminently proper that the Committee should testify, by its official action, its appreciation of his zealous and honorable service, continued constantly through many years.

Mr. Eldridge was the eldest son of Griffith M. Eldridge, for many years a prominent merchant of Philadelphia.

He was born in Philadelphia on January 3, 1831, and at the time of his death was in his 68th year. He traced his ancestry on both paternal and maternal sides to the earliest colonists of America. In 1838, his family removed to Cecil County, Md., where his early life was passed, and where he was fortunate in having as schoolmaster, Squire Hayes, a man of unusual ability for that position, and who filled, as well, the offices of Magistrate and General Surveyor until his death.

Mr. Eldridge was sent to Nazareth Moravian School to complete his studies, the foundation of which had been so well laid that even at this time he was accustomed to work out and plot the surveys which he had assisted his instructor to make.

Having concluded the course of study at Nazareth, he was for a time employed on the staff of Dr. James Higgins, Agricultural Chemist of the State of Maryland, after which

he entered the law office of the late Samuel H. Perkins, of the Philadelphia Bar, and was admitted to practice in 1853.

His natural fondness and aptitude for mechanics caused him, early in his professional career, to turn his attention to the practice of patent law, to which he remained devoted. His interest in scientific subjects soon attracted him to the Franklin Institute, with which he became connected as a member in 1874. He was elected a member of the Board of Managers in 1885, and served in that capacity until 1890.

Mr. Eldridge's special interest in the Institute, however, was centered in its Committee on Science and the Arts. He was enrolled as a member of this body when it was still a voluntary organization. When it was reorganized and made an elective body, he was largely instrumental in drafting the very efficient revised rules and regulations under which the Committee is at present operating. He was made one of the original members of the reorganized committee, and was continued in his membership by successive elections, to the time of his death.

Of the usefulness of his long and constant services to the Committee, his colleagues only can form a just estimate, and it must suffice here to record the fact that he earned the fullest measure of their esteem and gratitude.

## NOTES AND COMMENTS.

### ADVANTAGES OF MECHANICAL DRAUGHT OVER CHIMNEYS FOR BOILER FURNACES.

Mr. Walter B. Snow, at the recent meeting of the Northwestern Electric Association strongly advocated the substitution of mechanical draught in place of chimney draught for furnaces. This can be accomplished either (1) by forcing the air into a closed ash pit, and maintaining therein a pressure in excess of the atmosphere; or (2) by exhausting the air and gases from the flue or uptake, and thereby creating a partial vacuum which will cause a constant onward flow of air to the combustion chamber. The first method is designated as "forced draught" and the latter as "induced draught." In both types of mechanical draught centrifugal fans are used to render the draught conditions positive at all times.

The advantages of mechanical draught as stated by the author are its posi-

tiveness and flexibility. Its positive character renders its action independent of the weather; and its flexibility lends to it that characteristic so lacking in the chimney, the capability of exactly adapting the intensity of the draught as well as the volume of air to the requirements of the instant. Especially is this advantage noteworthy in cases where the service is irregular in character, that is, when the demand for steam is fluctuating, as, for example, in traction service where they are often sudden and immense.

Again, a convenient feature of mechanical draught, pointed out by the author, consists in the ability to burn cheap fuels, which are almost invariably of small size and require an intensity of draught which is not readily created by means of a chimney.

Also, the positiveness and intensity of the draught produced by a fan makes it a valuab'e aid in connection with the suppression of smoke—a question that is of the first importance in cities where soft coal is the only fuel used.

Turning to the economic side of the question, the author points out that the chimney is an absurdly inefficient means of creating an air movement, affirming that it can readily be shown that under the ordinary conditions of steam boiler practice a fan will remove a given amount of air with the expenditure of only one seventy-fifth of the cost required by the chimney. Other economic advantages are itemized, but need not be specially referred to The concluding portion of the paper contains a valuable statement of the comparative cost of the two systems, which should receive the careful attention of steam users. This is accordingly quoted :

"In order that a definite comparison may be made between the two methods of draught production, a certain 1,600 horse-power plant has been taken, of which the cost is known. This consists of eight modern water-tube boilers, two economizers, and a chimney 8 feet in diameter by 180 feet high. The latter is located just outside the boiler house wall. If a duplex induced mechanical draught apparatus, each fan capable of operating the entire plant, should be substituted for the chimney, it could be placed immediately above the economizers, and with its attached engines could be rigidly supported by beams resting on the economizer walls. A short stack would serve to discharge the gases above the roof.

"The cost of the chimney, with damper regulator and dampers, is $9,300; that of the fans, engines, draught regulation and short stack, installed complete, would be about $3,500, or only 38 per cent. of the draught-producing apparatus for which it is substituted. That is, the saving would be $5,800.

"With the increased draught produced by the fans it would be possible to raise the combustion rate and the steaming capacity, or, what is equivalent, the same capacity might be maintained with a less number of boilers Suppose one of the eight boilers be omitted from the original design, making the plant 1,400 nominal horse-power. A further saving of about $4,000 may thus be secured.

"If the land be valuable the reduction of space incident to the employment of mechanical draught may have an appreciable effect. If worth, say, $2 per square foot, the saving by omission of chimney and one boiler would be about $2,000. The total saving in first cost resulting from an expenditure of $3,500 for mechanical draught may thus be shown to be $11,800; that is, the saving is nearly three and one-half times the expenditure necessary to

secure it. Obviously there is a coincident reduction in the fixed charges for interest and taxes.

"The power expenditure for operating the fans should be practically appreciable in any well-designed plant in which provision is made to utilize the exhaust steam from the fan engine.

"The most direct saving in operating expense which may be secured by the introduction of mechanical draught is that resulting from the utilization of cheaper fuel. Such a plant as previously described would, under good conditions, probably require at least 8,000 tons of high grade coal per year, operating ten hours per day. If a saving of only 25 cents per ton could be effected it would represent an aggregate of $2,000 per year, a very good return on an investment of $3,500. But in many cases much greater savings may be brought about. A case in point is that of the United States Cotton Company, Central Falls, R. I., where, with a 1,000 horse-power boiler plant, the fuel originally employed with chimney draught was George's Creek, Cumberland, costing (at that time) $4 per ton. With forced draught a mixture of No. 2 buckwheat screenings and Cumberland is now used, costing $2.62 per ton. The saving has been about $125 per week, enough to pay for the special steam fan in about six weeks.

"Other direct and indirect advantages of mechanical draught might be presented, but the limits of the paper will not permit. If it were not for its rough-and-ready character the chimney would long ago have been discarded, because of its wastefulness. In the search for the highest efficiency such waste can no longer be ignored, and when dollars and cents are concerned, crude methods must give way to those of greater refinement. It is for this reason that the most progressive engineers of the present day are not only considering but adopting mechanical draught as a substitute for the chimney."

W.

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## POSSIBLE IMPROVEMENTS IN THE MANUFACTURE OF ALUMINUM.

*London Engineering* lately published a valuable summary of the present state of the aluminum industry, which contained an instructive analysis of the several items of cost in the manufacture, given on the authority of Professor Roberts-Austen, chemist to the British Mint. From this it appears that the current selling price of the metal is 33·2 cents per pound. The cost of production is estimated to be 27·2 cents per pound, of which only 2·2 cents is for electric energy consumed in its production, while the co t of the raw material is placed at 12 cents.

It is hopeless to expect any further reduction in the cost for power, which as appears from foregoing figures is extremely low. There is room, however, for considerably lessening the cost of the raw material used in the manufacture, and in this direction rather than in the invention of radically new methods of manufacture, there is reasonable prospect that a cheapening of nearly one-third in the present cost of production may be realized.

Becker, the former manager of the works of the Societé Industrielle d' Aluminum at St. Michel in France, to accomplish this object, proposes to substitute calcined beauxite, costing about 1 cent per pound, for the refined alumina generally used. Since 2·2 pounds of this calcined beauxite would

suffice to produce 1 pound of aluminum, it will be manifest, from the figures given in what has gone before, that this substitution would reduce the cost of aluminum by nearly 10 cents per pound.

The drawback to this suggestion, however, is the fact that the metal thus produced would contain considerable (perhaps 6 per cent.) of silicon and iron as impurities, and some cheap method would have to be devised to refine it. This is by no means an easy task, but is, nevertheless, within the range of practicability. This proposition is one which should appeal strongly to inventive metallurgists, since even the saving of a few cents per pound on the present cost of producing aluminum would be of immense importance to the industry. W.

## USE OF ALUMINUM FOR ELECTRIC CONDUCTORS.

At one of the electrical installations at Niagara Falls, the plan has been adopted of using aluminum in place of copper for the conductors, connecting the dynamos at the bottom of the shaft with the plant at the top of the cliff. The *Western Electrician* gives the following details:

"The bars used are 25 feet in length, 6 inches wide and ½ inch thick, four being used in parallel; every 25 feet they are bolted and riveted together; at the top they are connected with aluminum cables 1¼ inches in diameter and covered with rubber insulation; the ends are set into sockets into which melted tin is poured. The total weight of these aluminum conductors is about 22,000 pounds, while the same work would require 48,000 pounds of copper." W.

## AN IMPROVED ICE BOAT.

There has lately been turned out from one of the English shipyards a vessel designed as an ice-breaker, which embodies a novelty in construction that may add greatly to the efficiency of vessels designed for this service; the details of this construction are given herewith. One propeller is arranged aft, in the usual position, and another smaller propeller forward. The forward propeller, by giving to the water under the ice a high sternward velocity, deprives the ice of its support and reduces its resistance to crushing, so that the advancing bow of the vessel, which is arranged with a suitable overhang, cuts its way into the unsupported ice without experiencing either the shock or resistance to which former types of ice-breakers were constantly exposed. The vessel is of the following dimensions: Length, 202 feet; breadth, 43 feet; depth, 21 feet 9 inches. She will be fitted with two sets of triple expansion machinery of special construction. The vessel has been constructed for the Imperial Senate of Finland, and will be principally used in keeping the port of Hango open during the winter. W.

## OBSERVATIONS ON AUTOMOBILE VEHICLES.

One of the recent meetings of the Austrian Society of Engineers and Architects was devoted to the discussion of the present state of the automobile vehicle.

On the subject of motive power, there were considered steam, the various forms of internal-combustion motors—using petroleum, benzine, acetylene and similar substances—and electricity. Steam does not appear to play a notable part in connection with the development of this new means of transportation. The internal-combustion engines appear to have met with most general favor on the continent; while the electric-storage battery—which undoubtedly offers the most desirable and elegant solution of the motive power problem—has received the most attention, and most satisfactory application in England and America.

The transmission of the motive power to the point of application was considered the most difficult problem in connection with the design of automobiles. The mechanism required for this function differs materially for the different kinds of motors. The benzine motor, for example, runs at a constant speed of about 700 revolutions per minute, which must be reduced to between 25 and 100 revolutions on the driving wheels. Electric motors, while more readily controllable, still require considerable reduction. Steam, in this respect, has advantages over both the preceding types, but the objections to this medium for automobile service on other accounts are serious.

It was pointed out that many of the constructive details of motor vehicles have been adapted from the bicycle, the wheels, ball-bearings, pneumatic tires, etc., having been copied without change, except in dimensions. To this adaptation there can be no criticism.

Other portions of the design of automobiles, especially those supplied by the carriage builder, come in for severe criticism. In this category were placed the heavy leather work, dashboards and other details, very appropriate for horse propulsion, but quite incongruous when applied to the new service. It was concluded that motor vehicles have come to stay (figuratively speaking), but that there is still great room for improvement in their design and construction. W.

## A POSSIBLE NEW METALLIC ELEMENT.

In a memoir lately presented to the French Academy, reference was made to a new radio-active substance present in pitch-blende, and which the authors believe to be due to the presence of a new element. It is said to have a much more pronounced effect than uranium, as described by Becquerel. They propose for it the name "polonium," indicating the country from which the mineral was obtained. W.

## FUNGI AS A SUBSTITUTE FOR YEAST IN FERMENTATION.

It was reported at the recent meeting of the International Chemists' Congress, held at Vienna, that Dr. Calmette, Director of the Pasteur Institute in Lille, had succeeded in cultivating a fungus which entirely replaces yeast for fermentation. The following details have been published:

"Trials on a large scale have proved the enormous advantage afforded by the use of these cultivated fungi in the place of yeast. In the case of maize, brought to fermentation by means of the fungi, a much larger quantity and better quality of alcohol are obtained at considerably lower cost, the spirit

being cleaner and containing less empyreuma as a consequence of the absence of the microbes found in yeast. A ton of corn requires but a few grains of the fungi for purposes of fermentation. Dr. Calmette has further proved that this aseptic method of fermentation works with equal success in the factory and in the laboratory, whether employed on a large or a small scale, not one malignant microbe having been found in thousands of gallons." W.

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## A CELLULOID COMPOSITION FOR DRIVING BELTS FOR MACHINERY.

An English inventor has patented an improved belt material for power transmission which consists in using a suitable textile fabric as the basis, and impregnating this thoroughly—so that saturation takes place—with celluloid applied as a thin solution. The material is treated in this way in large webs or sheets, which is then cut up into strips of the required width and length. Several strips may be cemented together to secure a stronger belt, or a strip similarly impregnated with celluloid is used to envelop the other, which then forms a central core. By this process the belt is said to maintain its flexibility, while the celluloid, being incorporated into the texture of the fibers, gives the belt great strength, prevents stretching and renders it entirely waterproof. This last-named property is of much importance in many situations where the nature of the work forbids the use of cotton or leather. W.

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## MERCERIZED COTTON AND VISCOSE.

In the Zeitschrift fuer Angewandte Chemie there has lately appeared an interesting summary of the present state of the industrial applications of mercerized cotton of which the following is an abstract:

The origin of this new branch of industry is due to John Mercer, in England, in 1852. The original invention (treating cotton fiber with caustic) was lost sight of until it was revived by Depoullij in 1884, in one of the Alsatian cotton mills, to produce an imitation of crepe. A further extension of the invention was made by Messrs. Thomas and Prevost, who employed the process with the fiber under tension for the purpose of producing a silky luster on cotton. Thus far, however, the process has received only a limited application, although its use is extending. Recently Messrs. Cross, Bevan & Beadle, in England, by treating Mercer's alkali-cellulose with carbon bi-sulphide obtained a mass soluble in water which, because of its great viscosity, they called "viscose," and which they determined to be a solution of sodium cellulose xanthate. By several methods—such as spontaneous coagulation, heating, treatment with acids and such—the cellulose originally employed was found to be separated, though not in its fibrous condition, but as a plastic, translucent mass.

This "viscose" finds application in cotton printing and sizing, as a fixing material for pigments. It is also said to afford a substitute for celluloid, for sizing paper and for the production of numerous articles of ornament, such as are generally made from ivory, bone, horn, etc. W.

# Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, November 16, 1898.*]

HALL OF THE FRANKLIN INSTITUTE,

PHILADELPHIA, November 16, 1898.

MR. H. R. HEVL, in the chair.

Present, 126 members and visitors.

Additions to membership since last report, 13.

The Secretary reported a vacancy in the Committee on Science and the Arts, caused by the death of Mr. G. Morgan Eldridge.

Mr. J. J. De Kinder was elected to fill the unexpired term of the deceased member.

Mr. George D. Burton, of Boston, presented a communication describing an electrical process of his invention for unhairing and tanning skins, illustrating the subject with the aid of a number of lantern slides, and an electrolytic bath, in which the unhairing of a number of kangaroo hides was experimentally shown.

The process consists substantially in subjecting the skins, for unhairing, to an aqueous bath containing unslaked lime and a small addition of arsenic tersulphide, and passing an electric current through this bath with the aid of suitable electrodes. The internal arrangement of the bath and the manner of disposing the hides therein may be modified in various ways. The tanning process is substantially similar to the unhairing process, except that the desired tanning agent is introduced into the bath.

The inventor claims that the processes of unhairing and tanning are very materially facilitated by the use of the electric current in the manner just described, the operations being completed in a fraction of the time ordinarily required.

The subject was discussed by Dr. Goldschmidt, Dr. Wahl and the author. The inventions were referred to the Committee on Science and the Arts for investigation and report.

Dr. Chas. J. Hexamer read a paper describing his method for fire-proofing wood, with especial reference to rendering the woodwork of warships incombustible. After reviewing briefly the state of the art, the speaker gave an account of a series of experiments which he had made for the purpose. He had obtained the best results by the suitable injection into the wood of water-glass solution followed by a solution of sal-ammoniac, by which a deposit of silica was effected within the pores of the wood. The details of the operation were briefly described, and are reserved for publication.

The subject was referred to the Committee on Science and the Arts.

Mr. Wm. McDevitt, Inspector of the Philadelphia Board of Fire Underwriters, made some remarks on the inflammable and explosive properties of

smoke and their influences in causing the spread of fire. The speaker illustrated his remarks experimentally in a most instructive manner, with the aid of a model building.

The subject was discussed by Drs. Hexamer, Goldschmidt and the speaker.

Adjourned. WM. H. WAHL, *Secretary.*

## COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held Wednesday, November 2, 1898.*]

Reports on the following subjects were considered:

Passed first reading:

*An Inertia Indicator.* Wilfred Lewis, Philadelphia, Pa.

The following reports were adopted:

*Improvements in Pneumatic Dispatch Tube Apparatus.* B. C. Batcheller, Philadelphia.

ABSTRACT.—For a complete description of the Batcheller system, the reader is referred to the JOURNAL for August, 1898, *Art.* "Recent progress in the development of pneumatic dispatch tubes, by B. C. Batcheller."

The report finds that although a large number of patents have been granted to various inventors looking to the use of pneumatic tubes of sufficient size for the transmission of mail matter and parcels, the Batcheller patents were the first to form a complete system of practical value for larger tubes, in proof of which the report cites the successful application of this system to the 6- and 8-inch pneumatic dispatch tubes now in practical operation in Philadelphia, New York and Boston. The system is protected by a series of patents of the United States, granted to B. C. Batcheller.

For the skill with which the engineering details of the system have been worked out, and the ingenuity displayed in adapting the elements used in the inventions to their respective purposes, the award of the Scott premium and medal is recommended. [*Sub-Committee.*—A. Falkenau, Chairman; John M. Hartman, C. J. Reed.]

*Chimneys for Incandescent Gas Burners.* Ernest M. White, Philadelphia.

ABSTRACT.—For a full description, with illustrations of these improvements, the reader is referred to page 464 of this impression of the *Journal.* The invention is patented to applicant (see U. S. patent No. 589,323, August 31, 1897).

The report finds the White chimney to be an improvement over the narrow cylindrical chimney in common use. Being larger in diameter than the ordinary chimney, it allows an incandescent mantle that is worn or damaged to

be used for a greater length of time than would be possible with the ordinary straight chimney, the greater width of the chimney preventing the flame that extends through the rent from striking against and thus breaking the glass. The report finds that the applicant's claim, "that the illuminating power is increased over the ordinary chimney," is sustained only in the case of a broken mantle, "with which the illuminating power is slightly greater than with a perfect mantle, using either the cylindrical or the White chimney." A certificate of merit is awarded. [*Sub-Committee.*—Frank P. Brown, Charles A. Hexamer.]

*A Method for the Rectification of the Circumference.* Charles Morrell, Chicago, Ill.

ABSTRACT.—This method "is an attempt to effect, by means of ruler and compass, a construction which will yield a straight line equal in length to the quadrant of the circumference of a given circle, an undertaking necessarily foredoomed to failure." (The author's construction cannot be made intelligible without the aid of an illustration.)

The report finds that the method proposed by applicant gives a correct result only in case "$\pi = \sqrt{10}$, or, 3·162, a value too great by about two-thirds of 1 per cent." [*Sub-Committee.*—Edgar Marburg, Edwin S. Crawley.]

*A Method for the Quadrature of the Circle.* Charles Morrell, Chicago, Ill.

"The general observations introducing the preceding report are equally pertinent to the present subject. The quadrature of the circle, whether by the construction of a square equal in area to a given circle, or, as in the present case, by the construction of several elementary figures whose individual areas may all be expressed—as is here wrongly claimed—in terms of the powers and roots of rational numbers, is an attempt at performing that which, in an exact mathematical sense, is impossible." (The author's construction requires illustration to be intelligible.)

Applicant's construction, the report finds, on analysis, gives the correct result only if $\pi = 6 - 2\sqrt{2}$, or, 3·172; a value too great by about 1 per cent. [*Sub-Committee.*—Edgar Marburg, Edwin S. Crawley.] W.

## SECTIONS.

CHEMICAL SECTION.—*Stated Meeting*, Tuesday, November 15, 1898. Dr. Wahl, Chairman *pro tem.*

Dr. Harvey W. Wiley, chemist to the Department of Agriculture, Washington, D. C., made an address on "The Agricultural Possibilities of Our New Possessions." The speaker confined his remarks chiefly to the Hawaiian Islands, with incidental reference to the West Indian islands. The subject was well illustrated with lantern views.

The meeting passed a vote of thanks to the speaker for his instructive and

interesting remarks. The communication will appear in abstract in the *Journal*. W.

ELECTRICAL SECTION.—*Special Meeting*, Tuesday, November 8, 1898. Mr. Carl Hering in the chair. Mr. Wm. A. Rosenbaum, of New York, read a paper on "The Status of Electrical Invention," which was referred for publication. Mr. J. H. Cork described the Jenkins' improved lamp holder, for electric incandescent lamps. This invention affords a convenient means for automatically attaching an incandescent lamp firmly to iron work of any kind, in positions where light is desired, and which are difficult of access.

*Stated Meeting*, Tuesday, November 22, 1898. President W. E. Harrington in the chair.

Mr. A. J. Wurts, Pittsburgh, Pa., presented a paper, illustrated elaborately with experiments, on "Lightning and Lightning Arresters." W.

MINING AND METALLURGICAL SECTION.—*Stated Meeting*, Wednesday, November 9, 1898. Vice-President James Christie in the chair.

Mr. A. E. Outerbridge, Jr., presented a paper on the "Mining and Minting of Gold and Silver." The subject was illustrated with the aid of lantern slides exhibiting the processes of coining and assaying as practiced in the mints, and by the exhibition of a number of ancient and rare coins. These were projected by Mr. Fred. E. Ives, in apparent stereoscopic relief with the aid of a simple magascopic attachment to the lantern which he had devised.

Mr. Oberlin Smith, of Bridgeton, N. J., in the discussion which followed, gave an interesting exhibition with the aid of lantern slides, of a set of improved coining presses and other minting machinery, made by the Ferracute Machine Company, of Bridgeton, N. J., for one of the Chinese provinces. He gave an entertaining account of the difficulties and vicissitudes encountered in the task of sending the plant into the far interior of China.

Mr. Outerbridge followed with a communication on "The Microstructure of Bronzes," in which he called attention to the limitations of the method of microscopic examination for determining the physical qualities of the bronzes. The speaker illustrated his remarks by the exhibition on the screen of a series of photographic enlargements of microphotographs made from the same piece of metal under varying conditions.

*Special Meeting*, Wednesday, November 23, 1898. President A. E. Outerbridge in the chair.

The meeting was devoted to the discussion of the papers read at the preceding stated meeting, and to the discussion of the subject of "Specifications on Structural Steel and Rails." (The several subjects here referred to with discussion thereon will be published in due course.)

The meeting voted to recommend to the Institute the advisability of the Franklin Institute uniting as a body with the International Association for Testing Technical Materials. W.